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# SOIL SCIENCE

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## SOIL SCIENCE

### Contents for November, 1917

# THE INFLUENCE OF SODIUM NITRATE UPON NITROGEN TRANSFORMATIONS IN SOILS WITH SPECIAL REFERENCE TO ITS AVAILABILITY AND THAT OF OTHER NITROGENOUS MANURES

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## FOREWORD

For a proper understanding of our subject it is necessary at the outset to realize the conditions and factors influencing plant growth. Plant nutrition is a complicated process, due to the fact that plants synthesize their own plant-food from various substances taken out of the air and soil. These materials consist of carbon dioxide, water, oxygen, and suitable compounds of nitrogen, phosphorus, potassium, sulfur, calcium, iron, and, to a less extent, manganese and silicon.

Aside from the variations in the feeding of the plants, per se, the forces which affect the nutrition of plants may be designated as chemical, physical and biological.

Soils are chemically unlike because of their varied origins and processes of formation. The product of disintegrated rock and decayed vegetable matter, they partake of the nature of the materials from which they are formed. The natural processes of rock disintegration, uneven weathering of rocks of varying types, combined with the mechanical and chemical action of water, etc., have rearranged, sifted, and sorted the various materials once distributed with some uniformity into soils of many different types. Moreover, not only do they contain mineral plant-foods in sundry combinations, but also air, water and heat. The proper aeration of the soil, its adequate food supply, its warmth, are as essential to plant growth, as is fertility, using the word in the narrower sense. They contribute to its development in that they are among the agencies at work in the preparation of available plant-food. The relationship of soil air in opening up the soil and rendering it permeable to water; the relationship of water to solution, and of heat to ease of solution, are very potent factors in soil fertility. A dense and compact soil being slowly-penetrable by water yields its plant-food slowly and successive crop growth does not occur. Per contra, from a too open soil the water rapidly removes such plant-food as is soluble and the crop starves.

[1] Presented to the faculty of Rutgers College in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

The countless myriads of microörganisms in the soil are important factors in plant nutrition. The modern concept of the soil is that it is a living entity rather than a dead mass, a work shop in a store house, wherein microscopic forms are actively transforming the complex raw materials of the soil into simple forms suited for plant-food. Since their function viewed from the standpoint of soil management is the development of plant nutrients in the soil it follows that soil conditions which favor their growth enhance, and such as retard their multiplication lessen, the crop-producing power of the soil.

The climatic vagaries which are most apt to be harmful are the lack or excess of moisture. Moving through the soil column of varying depths and structure, the amount of this material supplied to plants, as well as the rate at which it is furnished, is of considerable importance to the maintenance of crop yield, regulating as it does the assimulation of food through the roots of the plants.

Of the plant-foods above mentioned, nitrogen is probably the most affected by these physical-chemical-biological forces. Because of the meager supply of this element in the soil and its urgent need for the rational feeding of plants, a knowledge of the influences that these forces exert on nitrogen transformations in soils is of considerable significance.

The economic problem of the nitrogen feeding of plants is of vital importance and becomes more and more urgent as time goes on and populations increase, and their needs become more complex. The physical and chemical influences which regulate the value of nitrogenous manures have been studied in detail by numerous investigators. The biological phase has been touched upon at various times.

It is the purpose of this thesis to consider, under a wide range of conditions, the biological phase of the soil nitrogen problem; noting the effect of fertilizer applications upon nitrogen transformations in soils in the hope that a more proper understanding may be reached with regard to the action of certain fertilizers frequently observed in fertilizer practices.

## INTRODUCTION

Nitrogen, the plant-food element of the greatest significance in the nutrition of plants, is fast becoming a limiting factor in crop production. With the increase in the world's population new efforts have been constantly put forth to raise more and larger crops. Consequently, the soil's nitrogen supply is being slowly but surely exhausted and means for its replenishment must assume consideration in the working out of soil problems.

As is well known, there are two main methods by which the nitrogen balance in the soil may be maintained, i.e., the growing of legumes, which when in symbiotic relationship with *Bacillus radicicola* add considerable quantities of nitrogen to the soil, and also the use of nitrogen-carrying materials of different kinds. With the possible exception of the nitrogen which may be

brought down in the snow and rain, and that fixed by non-symbiotic nitrogen-fixing bacteria in soils with proper energy relations, these two above-mentioned agencies are practically the only ones now available in keeping up the nitrogen supply of the soil.

A considerable amount of data has been submitted to show the value of legumes in adding nitrogen to the soil. The experiments, in the main, recommend the growing of legumes more often than is now practised, in order that the nitrogen balance be maintained. Unfortunately, our present economic conditions do not allow us to do this very conveniently, the ordinary three, four and five-year rotation, with a legume once in this period, being the common practice. It would seem, moreover, that the crop immediately succeeding the legume would be the one benefited most advantageously. Indeed, those crops some distance from the legume, in general, are often left nitrogen-hungry.

Necessarily, then, we must look to the second source for supplying us with this most valuable element of plant nutrition. In this country there is spent annually some $32,000,000 for combined nitrogen. This represents a large outlay of money and well merits the most careful attention of those who are to purchase nitrogen-carrying materials.

In choosing his source of combined nitrogen the purchaser has a wide variety of materials to select from, such as the mineral nitrogen carriers—$NaNO_3$, $(NH_4)_2SO_4$, $CaCN_2$, and $Ca(NO_3)_2$—the ammoniated superphosphates, and the organic materials, of which dried blood, fish scrap, farm and green manures are representative.

From our chemical conception of such materials we would expect rather marked responses from crops to any equivalent quantity of nitrogen in the above-cited materials. Necessarily then, one cannot be too circumspect in choosing the material which would net him the greatest return for the money invested.

## PART I

### *A review of the literature concerning the availability of nitrogenous manures*

The earliest fertilizing practices probably go back to the time of the Romans. Kimberley (85) in 1839 writes that saltpetre was known and used as long ago as the time of Virgil. Palissy (134) also remarked as early as 1563, "You will admit that when you bring dung into the field it is to return to the soil something that has been taken away."

About 1650 Glauber (49) in seeking for the principle of vegetation set up the hypothesis that it was saltpetre. Finding this material in the earth cleared from cattle sheds and applying it to soils, he found that it produced enormous yields. He likewise concluded that the fertilizing value of hair, bone, and shoddy was due to the saltpetre it contained.

Kimberley (85) also writes of English farmers testing the effect of different manures as early as 1670, and likewise quotes experiments down to 1828.

During the second quarter of the nineteenth century England and Europe saw the importation of large quantities of guano, nitrate salts and ammonia carriers. The results that these fertilizers produced were very astounding and greater importations took place. English farmers carried out any number of experiments with regard to their value, but like all experiments of this time they showed irregularities hard to explain. Moreover, considerable opposition was experienced from the teachings of Liebig (99), who preached eloquently against their use. Gradually, however, their use became more extant in agricultural practices, thereby bringing to the front the fundamental question concerning their use, i.e., their efficiency, or availability.

The prerequisite for such an understanding was a certain advance in chemical knowledge, which happily took place. Chemical analyses showed that the various nitrogenous manures varied greatly in their nitrogen content, and likewise in their fertilizing value. Tables were therefore constructed with the values of the manures in the order of their nitrogen content. No value was assigned to the character of the nitrogen, it seeming immaterial whether it was in the form of nitrates, bones, leather, rape seed or whatnot.

As experimentation went on, however, it was noticed that manures with equal nitrogen contents had very different fertilizing values. Guano exceeded all others in fertilizing value, and its action was, likewise, more quickly perceptible than that of any of the other forms supplying the same amount of nitrogen; something in the makeup was lacking in the others. Chemical analysis showed it to be rich in ammonia and since ammonia was already known as a plant-food it seemed quite easy to explain the rapid action of guano.

From this time on then, there was a distinction between what Liebig (99) called digestible and undigestible plant-food. The former included ammonia and nitrates, and the latter those which became available only when the nitrogen was converted into ammonia.

The fact that they now had a definite compound which they could weigh and calculate upon was a distinct advance in the availability question, allowing extensive experimental investigation. We thus had an unending number of field experiments in England and upon the Continent, the various nitrogenous materials including $NaNO_3$, $KNO_3$, $Ca(NO_3)_2$, $(NH_4)_2SO_4$, $(NH_4)Cl$ and a large number of organic nitrogen carriers such as the bloods, fish scrap, rape meal, and the guanos being compared as to their value for the nitrogen feeding of plants.

To these early experiments belong the work of Lawes (96) in England, Boussingault (15) in France, S. W. Johnson (96) Ritthausen, (153) Knop, (88) Deherain, (24) Maerker, (118) and Ville (201). These investigators, testing out the various nitrogenous manures on hundreds of soils, with different crops and under different climatic conditions, came to the conclusion that an equal quantity of nitrogen in the form of nitrates was better than the same quantity of nitrogen as ammonia, and this in turn was better than an equal quantity in organic forms.

However, there is much justifiable objection to this early work. In many cases no provision was made for the elimination of all but one limiting factor. Uniform soil conditions and the presence of an abundant supply of mineral plant-foods, were lacking in many instances, making the results open to question and criticism.

In 1881 Wagner (209) was led to propose the elimination of the cumbersome field trials and substitute for them pot and cylinder experiments. These methods of study, he argued, would allow of the more perfect control of the various factors in crop production. The tenability of his claims was only too apparent and thus we see the development of pot and cylinder experiments on a large scale by investigators the world over.

Wagner (208) himself carried out an immense amount of research on the nitrogen feeding of plants, directing especial attention to the value of nitrate of soda as a nitrogenous manure in comparison with a large number of fertilizing materials. His work entailed a study of the recovery of the nitrogen applied in different forms by numerous crops, among which may be cited rye, barley, oats, winter wheat, mangolds, spring wheat, mustard, carrots, potatoes and sugar beets; and under numerous soil conditions such as moisture, temperature, reaction and physical and chemical composition.

As a general thing he found in round numbers that out of every 100 parts of nitrogen supplied to the crop in the form of nitrate of soda, 70 parts were returned in the crop, whereas, with ammonium sulfate from the same 100 parts applied, he found returned in the crop 56 parts. This recovery, however, varied slightly with his crops; root crops or those crops having a long-growing season giving a higher recovery than short-season crops. His nitrogen returns in fertilizing oats were 74 parts, with rye 61, wheat 60, barley 64, mustard 55, rape 57, flax 77, potatoes 90, and carrots 91, when 100 parts of nitrate of soda were used. Similarly when ammonium sulfate was supplied, out of every 100 parts there was returned in oats 61, rye 56, barley 54, mustard 51, rape 39, flax 64 and carrots 72. His recoveries with the other organic manures were correspondingly smaller, varying with the quality of the materials supplied.

Taking into consideration all of the factors which would be involved in the action of these manures, such as a deficiency of lime in the case of ammonium salts, liability to leaching of nitrates, the gradual action of organic manures, which is quite desirable in some cases, he worked out a table of efficiencies giving the recovery from nitrate of soda a value of 100. Basing his other figures upon this he gives for ammonium sulfate a value of 90, for dried blood a value of 70, manure 45, and wool and leather 30 and 20, respectively. Checking his pot and cylinder experiments against field trials, with the same fertilizers he obtained the same order of availability although his relative values became somewhat lower. In his field trials ammonium sulfate was assigned a value of 75 instead of 90, as was found in his pot work.

As reported in another publication (211) he repeated his first researches

in 34 distinct experiments on 9 different soils and came to practically the same conclusions as he had previously reached.

However, in giving out these values he warns against generalizing too far. Organic nitrogen, he argues, cannot always be substituted for nitrate nitrogen, and conversely, nitrate nitrogen can not always replace organic nitrogen.

A vast amount of research has taken place since Wagner (209) first suggested his principles for studying the values of fertilizers. Some of the more important contributions are summarized in the following pages, particular attention being paid to the investigations of the last twenty years. For the sake of coherency the literature is summarized in groups which take up in turn: (1) the relative ability of $(NH_4)_2SO_4$; (2) the value of the new synthetic manures $CaCN_2$ and $Ca(NO_3)_2$; (3) the efficiency of the higher grade organic materials—dried blood, rape meal, cottonseed meal, etc., and (4) the lower grade nitrogen carriers—animal excrement, wool waste and the like.

Following closely upon the publication of Wagner and Dorsch's (208) work in 1892 we find Grandeau and Bertman (52) reporting along similar lines from France. In a field experiment for the seasons 1892–1897, growing corn, oats, wheat and potatoes, they compared the relative values of $NaNO_3$, $(NH_4)_2SO_4$ and dried blood, and assigned for them the figures 100, 82.90 and 71.30.

A year later, Thorne (192) in a 2-year field experiment compared $NaNO_3$ and $(NH_4)_2SO_4$ on a rotation of corn, oats, wheat and clover and reports a slightly higher value, namely 84, for $(NH_4)_2SO_4$.

In 1900, Warington (215) in speaking of the fertilizing experiments at Woburn and Rothamsted said that for cereals $(NH_4)_2SO_4$ had a value of 93, for hay 88, for mangels 82 and for turnips 100 when the action of an equivalent quantity of $NaNO_3$ is valued at 100.

Pfeiffer (141), in the same year, reports as a result of a 3-year pot experiment with oats, mustard, and carrots as the crops, that $(NH_4)_2SO_4$ should be valued at 87 if $NaNO_3$ is to be valued at 100.

Von Feilitzen (35), concludes from seven trials with $(NH_4)_2SO_4$ in moor soils that it should have a value of 91. In one trial with barley in a loam soil he got a value of 75, and with rye on a sandy loam he obtained a value of 75 also.

Von Sigmond (204) published the results of his pot-experiments in 1904. Using a poor sandy well well provided with lime he secured an availability of 90 for $(NH_4)_2SO_4$ when wheat, rape and buckwheat were grown.

Krietschmer (93), reporting coöperative experiments from the Bonn, Bernberg, Halle and Koslin Stations in Germany by the Wagner (209) method, confirms in general the latter's conclusions, although noting some exceptions.

As a result of pot experiments comparing the relative values of sodium nitrate and ammonium sulfate for the oat crop, Steiglich (178) would assign ammonium sulfate a value of 95, Sjollema (173), 95, Hansen (61), 91, Soderbaum (175, 176, 177), 88–95, Schreiber (168), 77 and Siebelien (172), 59.5.

For the wheat crop Vauha (200) reports a value of 96 and Soderbaum (175, 176, 177), 88. Likewise Berry (9), Behrens (6), Kuhnert (95), Liebenberg (98), and Schneidewind (164, 165, 166), all report greater values for sodium nitrate than ammonium sulfate for the growth of small grains.

As a fertilizer for corn and carrots, Schreiber (168) values ammonium sulfate at 77. In limed soils, however, he raises this value to 81.

Reporting the results of five years of experimentation at the Danish Experiment Stations, Hansen (61) concludes that for root crops ammonium sulfate should have a value of 71.

Somewhat higher results, on the other hand, were obtained by VanHock (198), in the Netherlands. This author finds a value of 99.5 for sugar beets, and for grains a value of 97.5. For potatoes $(NH_4)_2SO_4$ gave him better results on peat soils, but on the other types of soil $NaNO_3$ was superior. Vauha (200), on the other hand, found a value of 66 for root crops, while Von Feilitzen (35) gives it a value of 86 for these crops. Grieg (56) and Schmoeger (162) also found $NaNO_3$ superior to $(Na_4)_2SO_4$ for potatoes. Malpeaux (121) in testing the effect of these two fertilizers on mangels reports the test results from the fertilization with $NaNO_3$.

In a series of field experiments at the Maryland Agricultural Experiment Station, Patterson (137) states that $(NH_4)_2SO_4$ has not given as good results as $NaNO_3$ under any conditions. At Rhode Island Wheeler (220) found that the action of $(NH_4)_2SO_4$ was greatly accelerated by the presence of lime. This is likewise the experience of the Pennsylvania Station (221). Regarding the influence of lime upon the action of $(NH_4)_2SO_4$, Graudeau (51) says that from his work he would give it a value of 80 in unlimed soils, in moderately limed soils 86, but in heavily limed soils a much lower figure, 63, due no doubt to the loss by volatilization.

Perhaps the most authoritative work in this country on the subject of availability has been carried out at the New Jersey Agricultural Experiment Stations. This work was started by Voorhees and Lipman (205) in 1898, and is in operation at the present day.

In a 15-year cylinder experiment, with three 5-year rotations of corn, oats 2 years, wheat and grass, Voorhees and Lipman (205), and very recently Lipman and Blair (107) have found that by giving $NaNO_3$ a value of 100, $(NH_4)_2SO_4$ should be valued at 65. The fact that this experiment has been running for so long a period and has been carried out under such a diversity of conditions should establish it as one of the most authoritative in the world on the availability question.

Others who have contributed to the availability question showing the superiority of $NaNO_3$ over $(NH_4)_2SO_4$ are Bassler (5), Petermann (139), Hasselhof (66, 67), Eckenbrick (30), deGrazia (54), Gaskill (39) and Gerlach (40).

It is not difficult to find experiments where $(NH_4)_2SO_4$ has given results equal or even superior to $NaNO_3$.

Otto (133) reports that in light sandy soils, in warm wet seasons $(NH_4)_2SO_4$

gave him better results than $NaNO_3$. Kelley (80), Kellner (84), Trelles (194), all report the better action of $(NH_4)_2SO_4$ in the growing of rice.

Popisilki's (142) work shows the same general phenomena, as well as that of Kleberger (86), von Feilitzen (35) Kreitschmer (93), namely, that on open sandy soils in climates of abundant rainfall, $(NH_4)_2SO_4$ is liable to give better returns than $NaNO_3$.

Clausen (18), Wehnert (219), Bachmann (4), Suchting (187) Soderbaum (175, 176, 177), Lilenthal-Guethin (100), Orchimkov (132) and Wein (216, 217), all report $(NH_4)_2SO_4$ equal or superior to $NaNO_3$ in its action.

These numerous experiments with $(NH_4)_2SO_4$ show a wide range of returns, in some cases going above, sometimes below, and in other cases equal to $NaNO_3$. We may, with propriety, inquire into the underlying causes of such results.

In attempting to explain such phenomena Wagner (208) considers the presence or absence of lime of the greatest importance. In one of his experiments he found that without lime $(NH_4)_2SO_4$ has a value of 28, whereas when lime was present, this same relative efficiency became 90. This same opinion finds credence in the work of Clausen (18), Bassler (5), Deherain (24), Graudeau (51), Hasselhoff (66, 67), Hasselbarth (65), Patterson (137), Wheeler (220), Volecker (203), Thorne (193), White (221), Lipman and Blair (107) and a host of others too numerous to mention. This great necessity of lime as an aid to the rapid nitrification of fertilizing materials has also been shown in the laboratory by Müntz and Girad (129), Schloessing (160), Withers and Fraps (224), Warington (215) and others. A good bibliography concerning the influence of lime on the nitrification process may be found in the work of Kopeloff (91).

A second theory to the effect that the inferiority of $(NH_4)_2SO_4$ as compared with $NaNO_3$ finds support in the teachings of S. W. Johnson (76). This investigator believes that the inferiority of ammonium sulfate is due to its becoming fixed in the clayey portions of the soil. This view is also held by Wagner (211), Pfeiffer (140) and Löhnis (115). Pfeiffer found that, in some cases, the ammonia became so securely fixed, to added zeolites of calcium, that the plants were not able to use it.

This explanation is somewhat at a variance with our knowledge of soil nitrification processes. We know from Dyer's (29) work at the Rothamsted Station that nitrification proceeds very rapidly. In fact this investigator writes "the application of ammonium sulfate is in fact virtually tantamount to our application of nitrates." If such be the case very large amounts cannot be held very firmly fixed in the soil.

Yet another theory advanced by such authors as Schneidewind and Meyer (164), and Gerlach and Vogel (45), is to the effect that certain plants have selective tastes for either nitrate or ammoniacal nitrogen. Again we know from investigations of Godlewiski (50), Tacke (190), and Immendorf (74), that in the nitrification process there may be a loss of elementary nitrogen. If such is the case the differences in availability are easily comprehended.

As ammonia and nitrates are quickly transformed into protein forms within the microbial cell, we have yet another explanation for the differences in the fertilizing values of the two salts. Being taken out of the system by the microorganisms, it may or may not become available again during the current growing season. Moreover, the remineralizing of the nitrogen is attendant with the same liability to loss as is ammonium sulfate itself. With regard to this last-mentioned theory Wagner (211), thinks it is of a minor nature. He seems to be supported in his contention by the work of Vogel (202). Contrary to this, however, are a number of experiments to show that soluble forms of nitrogen are readily assimilated when suitable energy relations are present. In this connection one may cite the works of Biereima (10), Doryland (27), Stocklassa (179), Lutz (117), Stutzer and Rothe (186), and Kruger and Schneidewind (94).

Lemmermann (97) and his collaborators have shown that slight losses of ammonia occur in soils treated with heavy applications of lime and ammonium sulfate. They are of the opinion, however, that under practical field conditions this will not happen. Hall and Miller (60) found that more ammonia collected in vessels containing acid when placed over fields recently manured with ammonium sulfate, than on the untreated plots. Ehrenberg (32) records that when large quantities of ammonium sulfate and calcium oxide are applied to soils there are considerable losses by volatilization, varying with the wind. Potter and Snyder (143), in reviewing this literature, state that the results are conflicting and proceed to show that under ordinary field conditions appreciable quantities of ammonia are lost.

Wagner (208), also points out that applications of mineral nitrogenous fertilizers may even entirely fail. It may happen that the peculiar effect of the nitrogen taken up by the plant is restricted to an increase of the total nitrogen of the crop, without at all leading to an increase in crop yield. It is clearly brought out by him that when the soil itself is capable of furnishing enough of nitrogen for practically a maximum plant growth, then the addition of sodium nitrate or any other soluble form of nitrogen cannot materially increase the quantity of the produce.

Summarizing the explanations for the differences in availability between sodium nitrate and ammonium sulfate we have: (a) the lack of lime, (b) fixation by soil zeolites, (c) selective preference for the source of nitrogen, (d) loss of elementary nitrogen in the nitrification process, (e) the transformation of soluble nitrogen into microbial protein, (f) loss of free ammonia in soils heavily limed, (g) lack of effort due to the soil's own nitrogen supply.

The instances where ammonium sulfate has shown to better advantage than equal quantities of nitrogen in sodium nitrate are not hard to explain. We may conceive of conditions which militate against the very advantages of sodium nitrate. Its ready solubility, ease of diffusion, renders it readily subject to removal in periods of *excessive* rainfall. Ammonium salts, on the other hand, because of the fact that the very valuable portion becomes tem-

porarily fixed, is less liable to loss by leaching. Thus on open sandy soils, sodium nitrate has been found to give inferior results compared with ammonium sulfate if the seasons are wet. Again, on heavy soils, continued one-sided fertilization with sodium nitrate may leave residues that are detrimental to the physical structure of the same.

Of comparatively recent origin are the newer synthetic nitrogenous manures, calcium cyanamid and calcium nitrate. Their recent entrance into the fertilizer trade has not militated against an accumulation of experimental data to attest their value. In reviewing this portion of the availability literature, experiments with calcium cyanamide seemed to hold an important place.

Wagner (210), who was among the first to experiment with this new fertilizer from a result of pot experiments with carrots, oats, barley, fodder and sugar beets, on nine different kinds of soils, concludes that it was equal in value to ammonium sulfate having a relative availability of about 90. He advises, however, that it be applied several days before planting and only upon soils in good physical condition.

In direct contradiction to this is the work of Svoboda (189) and Kuhnert (95). Svoboda, testing this manure on the growth of fodder beets and potatoes, obtained absolutely negative results; Kuhnert found in fertilizing sugar beets that he obtained a financial loss. With oats he secured somewhat better results, but the increase did not pay for the cost of the fertilizer. These negative results are no doubt due to the fact that they used large quantities on very poor soils.

Schneidewind (166, 167), Soderbaum (175, 176, 177), Vauha (200), Rhodin (150), Urban (197), Rossler (154), Hansen (61), Libenberg (98), Schulze (170), Sebelien (172) and Sjollema (174), found somewhat lower values with the use of this material. Hansen, Schneidewind, Urban, and Vauha record a value of 41, 68.5, 86 and 58, respectively, when $NaNO_3$ is considered as equal to 100. Urban, however, finds that his value fluctuates with the rainfall, reaching much lower values in dry seasons.

For the oat crop Soderbaum (175, 176, 177) gives a value of 92, for rye from 44 to 69, and for wheat 61 to 68. Schneidewind (166, 167) gives it a value of 89 and Vauha (200) 89 for wheat. Likewise Stutzer (185) and Sebelein (172) have also reported experiments to attest the value of $Ca(CN)_2$ on small grains. The former records a value of 82 for the oat crop and the latter 54, all the above values being calculated on $NaNO_3$ as 100. On the other hand, Hendrick (70) and Molinari (128) report that $Ca(CN)_2$ was as effective as $(NH_4)_2SO_4$. Others who have reported similar conclusions are Müntz and Nottin (130), Uchiyama (196), Rhodin (150), Sjollema and de Weldt (174), and Bassler (5). Sjollema (173) reports to a value of 120 for it with $NaNO_3$ as 100 and Bassler rated it at 103 from the results of his work.

Soderbaum (175, 176, 177) reports that with small and large amounts of the fertilizer, he obtained inferior results as compared with $NaNO_3$, but with intermediate amounts, 50 pounds per acre, he received better results.

As a top-dressing material this fertilizer seems to be very unfavorable. Gilchrist (48), Grieg (56), Schultze (170), and Wein (216) all report injurious effects from its use for this purpose, due to the very drastic action it has upon the foliage.

A survey of the literature also seems to indicate that some little time needs to elapse between the application of this fertilizer and the planting of the crop. Behrens (6), Haselhoff (66), Kahn (78), Knierim (87), Otto (133), Steiglich (178), Wagner (210) and Zeilstroff (226) have published work relating to the time which should elapse between application and planting. Behrens thinks that six days are enough, while Haselhoff goes so far as to advise fall application. Kahn would recommend thirty days in light sandy soils and Knierim, Otto, and Zeilstroff recommend from one week to fifteen days.

Soil conditions also seem to be a much more important factor for the best action of this manure than of $NaNO_3$ or $(NH_4)_2SO_4$. Immendorf (75) says it is not adapted to acid or light sandy soils. This idea finds confirmation in the work of Sebelien (172) who gave it a value of 22 for the mustard crop in a light sandy soil. Remy (148) is of the opinion that its most favorable action is on clay soils. He says that four weeks are necessary to overcome its toxic effects. Uchiyama (196) concludes that neutral soils are best and sandy soils are very bad for its action. This is especially so in dry seasons Gilchrist (48) reports, and is supported in this respect by Urban (197) and deGrazia (53).

A summary of the effect of lime nitrogen as reported by various European investigators is to the effect that it is not adapted to acid humus, or light sandy soils. Its action, however, can be improved on such soils by means of lime, the best results being obtained on fine-textured soils, rich in lime and organic matter, and well supplied with microörganisms which can convert it into ammonia and nitrates. As a general average it would seem that it had a fertilizing value somewhat inferior to $(NH_4)_2SO_4$, the best results being obtained with potatoes, the poorest with beets, and intermediate results with grains. When bacterial action is deficient dicyanamid if formed which is very injurious to plants. If moisture is a factor or lime is deficient ammonia is formed by chemical means. Thus the need of a potent soil flora is very evident for the success of this fertilizer.

Calcium nitrate in all possibility occupies a position in the availability table similar to that of $NaNO_3$. A number of investigators have reported that in soils deficient in lime this fertilizer gives results quite superior to $NaNO_3$. This seems to have been the experience of Wagner (211) and Stutzer (184, 185), in their availability studies on potatoes, oats and sugar beets. Schloessing (161), Sebelien (172), Steglich (178), Schneidewind (166, 167), Passerin (136), Limay (101), Stohr (181) and Belleroux (8), all conclude that $Ca(NO_3)_2$ is equal to $NaNO_3$. There are some dissentors, Greig (56), Rhodin (151), Hansen (61), Dudgeon (28), and Bassler (5) finding that $NaNO_3$ gave them the best results. Grieg (56) finds that $Ca(NO_3)$ did not give him good results on potatoes and Rodin (151) notes that on crops like oats, not requiring lime to any great

extent, $Ca(NO_3)_2$ was inferior to $NaNO_3$. Hansen (61) reports a value of 76 for roots and 88 for grains. Bassler (5) commenting on its use in moor loamy soils for rye and oats, gives it a value of 96 for both crops. Gerlach's (43) field experiments would give it a value of 74, whereas his pot experiments value it at 103. Soderbaum (176, 177), also considers $Ca(NO_3)_2$ of less value for grains, giving it a value of about 96. Schneidewind (166, 167) and Rhodin (151) in later papers give it a value of 96 and 98, respectively. It would seem then, taking everything by and large, that this fertilizer is practically equal to $Na,NO_3$, provided its poisonous principles, i.e., nitrites, are absent.

The organic sources of nitrogen are as numerous as the experiments recording them. Under this heading come the effectiveness of the various guanos, blood, bone, fish and meat meals, farm and green manures, as well as the extremely inert substances such as peat, leather and wool waste.

In discussing the availability of the guanos Wagner (208) says that fish guano has a value of 78 when $(NH_4)_2SO_4$ is valued at 100. The same author gives Dumara guano a value of 91, and Peruvian guano a value of 87. Schneidewind (166) considers animal guano at 67 and Pfeiffer (141) sees in fish guano a value of 64. Most of these experiments with guano seem to have been carried out with no attention to the fact that this material also contains large quantities of phosphoric acid. In this connection might be cited the work of the Rhode Island Experiment Station (63) on the phosphoric acid value of different guanos.

Various authors have worked upon the efficiency of farm manures. Gerlach (41) gives stable manure a value of 41, and cow manure 18, when $NaNO_3$ is considered at 100.

Voorhees and Lipman (206) differentiate the values of the different portions of manure, assigning a value of 35.9 for solid fresh manure, for the liquid and solid together 53, and liquid portion leached 43. Lipman and Blair (107) continuing the experiment, have obtained similar figures.

By means of pot experiments Von Sigmond (204) also obtained data for the value of manure in different conditions; calling $NaNO_3$ 100, he gives for fresh manure in the spring a value of 49, the same applied in the fall 48, rotted manure applied in the spring a value of 42 and for rotted manure applied in the fall 58.

Gilchrist (47) used fresh manure, manure kept long enough to be in good applicable condition and old manure stored in a heap for months, and found that that which had not been stored too long gave the best results.

Rudorf (155) gives cow manure a value of 23.3. Maercker (119) who has also worked on the availability of cow manure gives it a much lower value than this. Pfeiffer (141) gave sheep manure a value of 48.2, horse 29, cattle 26, and barnyard manure 19.2 when $NaNO_3$ was considered as 100.

Schneidewind (163) in field experiments received a recovery of only 8.13 per cent of the nitrogen applied in three years. Pfeiffer (141), on the other hand, in the course of three years obtained a recovery of 48.4 per cent on

the first year with potatoes, 9.8 per cent and 4.3 per cent, respectively, with rye and carrots the second year and only 0.8 per cent the third year. He recovered in all 63.4 per cent in the three years. His recoveries are abnormal however, because of the open sandy soil he employed and an abundant supply of lime and minerals.

A similar experiment is reported by Schulze (171) who gives much lower results than those reported above. In a 4-year experiment his total recovery was 23 per cent; 43 per cent of this was obtained the first year, 27 per cent the second year, 16.63 per cent the third year and 12.6 per cent the fourth year. The crops grown included oats, barley, wheat, rye, flax, potatoes and sugar beets.

Doiarenko (26) also reports the poor utilization of manure nitrogen, as well as Summers (188) in his work on truck crops.

With regard to liquid manure Mer (125) in comparing urine with $(NH_4)_2SO_4$ received the greatest profit with small applications. Pfeiffer (141) gives it a value of 49 and Hansen (61), regards its fertilizing value as 65 for roots and 72 for grains.

The peats have been given considerable attention as a fertilizing material. Because of the extensiveness of these reports it seemed advisable to see just what value various investigators ascribed to them. Herman (71), comparing rye straw, manure and peat litter and moor peat against no nitrogen, finds that 100 parts of peat nitrogen are as valuable as 2.6 parts of manure nitrogen. This would bring peat pretty low in the availability scale. Lipman (111) likewise finds peat to have a low availability, giving it a value of 10 when $NaNO_3$ is 100. Hoc (72) finds peat nitrogen to be valueless other than on heavy soils where it has perhaps a beneficial physical influence. However, some investigators seem to think that peat nitrogen can be made available by composting it with fermenting manures. For references to this practice the author calls attention to the work of Johnson (27) and Weiss (218). Turning our attention to another class of organic manures, the so-called green manures. we note that von Sigmond (204) finds for vetch a value of 78 and for alfalfa 59. Schneidewind (165) reports peas, beans and vetch to have a value of 52.5 and beet-tops 43, when $NaNO_3$ is taken as 100. Wagner (208, 210, 211) gives green manures a value of 80. The work at the New Jersey Stations (110) values green manures at about 50 to 60, depending upon the crop.

The fourth class of nitrogenous materials consists of dried blood, tankage, cottonseed meal, meat and fish scraps, etc. Wagner (208, 210, 211), considering $NaNO_3$ as 100, values the nitrogen in blood as 70, that in bone meal and dry ground fish at 60, and that of wool waste and leather at 30 and 20, respectively.

The results of the long-term cylinder experiment at the New Jersey Stations (107) give blood a value considerably below this, 60.7. A yet lower figure is noted by Schneidewind who gives it a value of 56. Von Sigmond (204) in his pot work rates dried blood at 72; likewise Rossler (154), and Hartwell (64) at

Rhode Island values it at 80 per cent of the value of $NaNO_3$. Graudeau (51), Thorne (193), Johnson (76), all give it a value between 70 and 80 when $NaNO_3$ is taken as 100. The other organic manures fall considerably below this and should be considered as nitrogen carriers only under exceptional conditions.

The lesser efficiency of dried blood and the other forms of organic nitrogen as compared with the mineral forms is not difficult to understand. In the complicated process of decay preceding the formation of ammonia there are many conditions under which elementary nitrogen may be formed. The greater the resistance to decay, the more prolonged is the ultimate simplification, and necessarily the attendant chances for loss increase. In so far as the growing crop is concerned, the substances which nitrify more readily will have the nitrogen in a digestible form when the plant has need of it, and not at some time after growth has ceased. This in itself is a big factor in the working out of relative values.

Again the character of the material supplying the nitrogen is of considerable importance in determinng its value. Materials of a wide carbon-nitrogen ratio in a fresh condition will give less nitrogen to the growing plant than fresh materials of a narrow carbon-nitrogen ratio, due to the rapid assimilation of nitrogen by soil microörganisms. On the other hand, materials like peat and leather will give the crop very little nitrogen because they are so extremely resistent to decay.

Considering the residual values of the mineral manures, as a whole, we find that they leave very little residue—their action seems to be spent during the season in which they are applied. As proof of this we may consult the work of Hall (58), Lipman (107) and others.

The residual effects of the organic manures may be somewhat greater, due, perhaps, not to the nitrogen supplied but to their influence in improving the physical condition of the soil. Rothamsted reports that barnyard manure applied 35 years ago still gives evidence of benefiting the plant. A close analysis of the conditions, however, shows us that other factors than mere residual effects have entered in.

The lasting effects of manures may not always be desirable. These organic substances which change but slowly necessarily produce soluble material after the crop has been taken off, which may be removed from the land by fall rains and lost to the crop.

While there is, then, a very considerable range of variation in the returns from any given quantity of nitrogen, a more or less definite relation still persists which enables one to classify nitrogenous manures according to the readiness with which they can enter the plant tissue. From what has been related in the text it would seem that there is no longer any doubt as to the superiority of nitrate over ammonia salts, which are in turn superior to $Ca(CN)_2$ or any of the organic forms.

This entire question of availability is one of extreme importance in all sections where fertilizers are used. Yet, notwithstanding its importance, it

is scarcely appreciated by the average user of commercial fertilizers. To him quantity is the desideratum, with quality considered very seldom. If he would but stop and think of the economic side of the question he would conclude as does Lipman (107) when he says:

> According to the schedule of trade values adopted by the New England States and New Jersey in 1915, the nitrogen in ammonia salts is given a value equal to that of nitrate of soda, viz., 16.5 cents per pound, the organic matter in mixed fertilizer is valued at 19 cents per pound, while the nitrogen in fine ground fish, meat, and blood is valued at 23 cents per pound. . . . . To state the matter in other terms, if the nitrogen in 100 pounds of nitrate of soda is worth \$2.25 then its equivalent in ammonium sulfate would be worth approximately \$1.78 and its equivalent in dried blood would be worth \$1.53. The trade values however, would make the nitrogen in 100 pounds of nitrate of soda and its equivalent in ammonium sulfate, each worth \$2.25 and the equivalent in dried blood worth \$3.56, the latter being more than twice its value as shown by the results of fifteen years of experimental work. To be sure, under a wide range of field conditions, the result would be less disadvantageous to ammonium salts and certain nitrogen plant-foods.

To the thoughtful person, the question must arise as to whether the present adjustment is a fair one. The plea is made that nitrate nitrogen is lost by leaching, but the results of numerous experiments show that the residual effect of $(NH_4)_2SO_4$ is no greater and that of dried blood only slight. Also, the residual effects from farm yard manures are entirely spent after the third year, and if much money is tied up in such fertility it is not an economic success. Even it if is granted that on certain sandy soils nitrates are lost in the leaching, still the higher returns would point to the advisability of using it, in smaller, and more frequent, applications.

It will be seen from the above review also that different investigators obtained recoveries from any given fertilizer that were far from constant. Varying proportions of the nitrogen applied being returned in the crops. That is to say, the readiness with which the nitrogen of the applied fertilizer is transformed into plant tissue seems to be influenced by factors which we may call external and internal. The internal factors pertain to the mechanical and chemical composition of the nitrogenous manure and are entirely apart from the character of the medium in which the decomposition takes place. For instance, it was seen that in the same soil and under the same climatic conditions the nitrogen in manure was more available than that in peat, or the nitrogen in blood was more efficient than that of the manure. It need hardly be added here, that the internal factors cannot be controlled as readily as the external factors. However, the latter factors the farmer has some means of controlling. He has it in his power to modify moisture, temperature and aeration conditions sufficiently to hasten decomposition processes and to increase in a large measure the solubility of the nitrogenous materials present in, or added to the soil. The work of Wagner (208, 210, 211), Pfeiffer, (141), von Sigmond (204), Lipman and Blair (107), Voorhees and Lipman (205), has intimated that the reason why more or less of the applied nitrogen is returned to the crop is because of the differences in crops themselves, in their root

systems, in growing season, etc. Wilfarth, Römer and Wimmer (222), on the other hand, would have us believe that the lessened recovery is due to losses entailed in metabolic processes.

Again, the work of Tucker and von Seelhorst (195) has shown us that the moisture supply is very important for maximum recoveries of nitrogen and increased crop growth. In a series of pot experiments where they added 0.5 gm. of nitrate of soda to a soil in combination with the other essential plant-food elements, they found that they got no increase in a crop of oats when only a little water was supplied, the supply of nitrogen in the soil being sufficient for the crop needs, the water and not the nitrogen being the limiting factor. When more water was added the plant made growth and utilized the nitrogen supplied, the added nitrogen, in this case 0.5 gm., increasing the crop 10 grams. One-half gram more of $NaNO_3$ was then added, but was without effect, the water again being the limiting factor. More water was then applied to the pot containing the first 0.5 gm. of $NaNO_3$ and the crop yield was increased to 20 gm.; but this does not represent the whole possibility because the application of the second 0.5 gm. of $NaNO_3$ gave a still further increase of 15.5 gm. Perhaps, then, the moisture conditions in the soils were a factor regulating the amounts of nitrogen recovered by the crop. However, the presence of a too generous supply of moisture may create conditions favorable to denitrification. For a review of the literature and discussions of this phase of the availability question, one is referred to the work of Voorhees (205) and Lipman and Blair (107). With regard to the loss of nitrogen by leaching and its bearing upon the availability question, much has been said and written.

The data of the most wide-spread knowledge were collected by investigators at the Rothamsted Station (57). By means of lysimeters, with which they were able to tap the soil column at any desired depth, they have found what they believe to be an average loss of 30 pounds of nitrogen per annum.

Collison (22) at the Florida Station, however, by means of his lysimeter work, has just recently recorded enormous losses of nitrogen per acre per annum.

McGeorge (123) at the Hawaii Station concludes from his laboratory experiments that the sodium nitrate, not being absorbed by Hawaiian soils, is very liable to be lost in the drainage waters. However, it must be brought to the reader's attention that the conditions of his experiment are so manifestly artificial that their application to actual field conditions is not tenable. The fact that large losses of phosphate and potash salts were found, under the conditions of his experiment, would substantiate this. In his work the possibility of soluble salts rising again to the surface by capillarity were entirely eliminated by his method of studying the problem. That this is an important item can be seen from the experiments of Malpeaux and Lefort (120) who found that quantities of sodium nitrate placed at a distance of 1 meter under the surface of the earth, reached the upper 6 inches of surface soil in less than 6 weeks. This same criticism may apply also to the work of other investigators (22, 57).

Hall (57) likewise states,

On the Rothamsted soil ammonium salts are not retained as such for more than the season of application, nor are the nitrates resulting from them able to return to the surface to feed the succeeding crop. On other soils of better texture for allowing the movement of water by capillarity there can be no doubt that the nitrates in the subsoil will return to the surface and be of service to the crop.

This corroborates the statement of Malpeaux and Lefort (120).

Collison's (22) figures on the enormous loss of nitrates by leaching are open to two criticisms. First, it seems to the writer hardly justifiable to tap the root zone at the point which he did and call the drainage obtained at this point lost to further crop growth. It has been shown by Miller (126) in a study of the root systems of agricultural plants, that many roots reach the point at which these investigators tapped the soil water, and are able to use the plant-food tabulated as lost. Furthermore, the conditions under which the soils were placed in the tanks allow of a very rapid nitrification of the soil organic matter, as has been shown by Deherain (25), and consequently the losses recorded are many times more magnified than would actually be the case.

Hall (57) also seems to show that the movement of nitrates in the ground is not as rapid as is generally supposed; i.e., nitrates in the ground water of treated plots did not mingle with those of the non-treated.

Moreover, it is a question in the writer's mind whether the figures representing losses of nitrates by leaching are truly representative of the facts. If we should consider the total drainage of the rivers of the world (17) we should find that there is annually deposited into the ocean some $24,614 \times 10^3$ metric tons of $NO_3$ per annum, or $5,513 \times 10^3$ metric tons of the element nitrogen. As this amount of nitrogen comes from a drained area of 40,000,000 square miles, calculated to the acre basis this loss would become very little indeed, i.e., 4 pounds per annum.

However, it cannot be denied that nitrates are susceptible of being driven down to the lower depths of the soil by means of copious rains and by the time they rise again to the surface are of little use to the crop that season. This, of course, would be reflected in availability studies. The question might also be raised as to whether the irregular recoveries obtained by the numerous investigators is due to purely physiological causes or whether it may possibly be effected by bacteriological activities.

A survey of the literature will show us that mineral salts applied to the soil increase to a large extent the already large host of soil microörganisms. We also know from the investigations of Caron (16), Stocklassa and Ernst (180) that the bacterial population under any specific crop is variable. Moreover, the extensive researches of Biereima (10), Hutchinson and Marr (73), Lutz (117), Lipman and Brown (112), Löhnis (114), Ritter (152), Stutzer and Rothe (186) and Vogel 202) have indicated that such substances as $NaNO_3$, $Ca(NO_3)_2$, $(NH_4)_2SO_4$, dried blood, and cottonseed meal serve as a source of food to the hungry hosts of soil organisms, and hence we would naturally ex-

pect a reflection in the growth of the plant. Seeking in nitrogen a portion of their food supply, or even energy for their life processes, they multiply the number of its combinations, compelling it to pass through a series of analytical and synthetical changes. The nitrogen of today, a constituent part of some protein molecule, may tomorrow be part of some simple amino-acid, or may unite with some other nitrogen atom and pass away into the air. Conversely, the simple soluble nitrogen in nitrate or ammonia salts today may be part of a complex protein body in a short while, and so on. There is an ever-changing condition of the nitrogen in soils.

It is because of the intimate relation between soil organisms, soil nitrogen and soil fertility, and the frequently controlling position of soil nitrogen as a factor in crop production, that there is such a strong interdependence of soil microbes and soil fertility. It can be no matter of indifference to us what the effects of these fertilizers are on the several processes of ammonification, nitrification, denitrification, nitrogen assimilation and nitrogen fixation. These processes possess for us a paramount interest because they are concerned with this very element whose fortune is so closely allied to the activities of soil organisms. The discovery and comprehension of the biological forces relating to the application of $NaNO_3$ to the soil is unquestionably necessary to the solution of many soil problems. An adequate knowledge as to the effect of $NaNO_3$ alone, and in combination with other fertilizing materials, upon the myriads of soil microörganisms is essential for a clearer understanding of the factors affecting the availability of nitrogenous fertilizers.

## EXPERIMENTAL

Experimentation has taught us that higher plants cannot assimilate atmospheric nitrogen or nitrogen in the condition that we find it in the higher protein complexes. In other words, the nitrogen must be in a digestible form before it can be of use in plant nutrition. The agencies by which these protein molecules are broken down are of two kinds, chemical and biological. Whereas the former acts only in a minor capacity, the latter is of the uttermost importance for the simplification of the protein molecule This process of simplification is carried out by many groups of soil organisms, among the most important of which are the ammonifying group and the nitrifying group. The process by which organic matter is transformed into ammonia we call ammonification. It represents a certain stage in the cleavage process, and because of the fact that the protein molecule must be split to this stage at least before it can be used by the plant, it bears an intimate relation to soil fertility conditions. Moreover, this stage must be reached before further mineralization of the nitrogen can take place. It is of no little concern to us, therefore, how this process of ammonification is influenced by the prevailing fertilizer practices. We know that the presence of a proper supply of nitrogen may be the limiting factor between a rich and a poor harvest.

Because of the fact that $NaNO_3$ is so extensively used in the present-day fertilizing practices, it is important to become acquainted with the influence that this salt has upon the ammonification processes in the soil. In noting this it should be studied from all possible angles—in acid and alakaline soils, in the presence of phosphates, in potash carriers, and in complete fertilizer mixtures. The influence of this salt upon biological activities at different degrees of moisture and temperature should be studied in detail in order to determine its effect on the various groups and types of microörganisms.

The purpose of the first series of experiments was to study the influence of $NaNO_3$ upon ammonification. Earlier workers such as Lipman and Brown (112), Temple (191) and Sackett (158) have noted that nitrates increased the ammonifying efficiency of soils. Quite recently Greaves (55) has come to the same conclusion. On the other hand, the work of Peck (138) and that of Crowther (23) seem to indicate a decrease in the accumulation of ammonia due to the presence of nitrates in the soil. Wohltmann (225) and his associates, testing the influence of soils treated with $NaNO_3$ at the rate of 75 kg. per acre, obtained an increase of over 3 per cent due to this treatment, the Remy (147) method being used. We thus have some inkling as to what to expect from fertilization with $NaNO_3$.

## SOILS USED

The soils used in this investigation were of seven distinct types. Six mineral soils and one of organic origin were used. The soils represent large areas of land in the various localities from which they were obtained. They were a Carrington loam from the Iowa Experiment Station; a Norfolk very fine sand, and a Norfolk sandy loam from Norfolk, Virginia; a Penn clay loam from New Brunswick, New Jersey; a Sierra sandy loam from Riverside, California; a Wooster silt loam from Wooster, Ohio; and a Muck soil from Great Meadows, New Jersey.

The writer takes this opportunity to thank those who have been so kind as to coöperate in collecting these soils.

The hycroscopic mositure, apparent specific gravity, water-holding capacity, lime requirement by the Veitch Method, nitrate content and ammonia content of the soils used are given in table 1.

In table 2 is to be found the capillary rise of water in the soils in centimeters at the end of various intervals of time. The capillary tubes were 1 inch in diameter and 30 inches in length. The figures in table 2 were obtained by allowing the tubes, after being carefully filled with soil, to stand in 1 inch of water for 42 days. It was thought important, inasmuch as sodium nitrate is a very soluble salt, to note this capillary rise, as a factor in alleviating toxic effects of large quantities of the salt.

TABLE 1

*Hydroscopic moisture, apparent specific gravity, water-holding capacity, lime requirement, nitrate content and ammonia content in the soils used*

| | SOIL NUMBER | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Characteristic...... | Carrington loam | Norfolk sand | Norfolk very fine sand | Penn clay loam | Sierra sandy loam | Wooster silt loam | Muck soil |
| Hydroscopic moisture (per cent)... | 2.35 | 1.00 | 0.15 | 2.28 | 1.35 | 1.87 | 18.00 |
| Apparent specific gravity.......... | 1.05 | 1.30 | 1.52 | 1.05 | 1.61 | 1.25 | 0.70 |
| Water-holding capacity.......... | 0.50 | 0.32 | 0.34 | 0.50 | 0.28 | 0.42 | 1.60 |
| Lime requirement... | 3,700 | 2,200 | 550 | 1,110 | Alkaline | 4,300 | 5,200 |
| Nitrates (mgm. per 100 gm. soil)...... | 2.66 | 1.67 | Trace | 4.78 | 4.79 | 2.60 | 13.30 |
| Ammonia (mgm. of a 100 gm. soil).... | 0.77 | 0.06 | Trace | 0.53 | 0.13 | 0.50 | 42.17 |

*Veitch method.

TABLE 2

*The capillary rise of water in the soils*

| SOIL TYPE | HOURS | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4 | 36 | 60 | 84 | 108 | 134 | 168 | 241 | 292 | 350 | 518 | 840 | 954 | 1022 |
| | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* | *cm.* |
| Carrington loam...... | 16.32 | 36.19 | 38.87 | 42.42 | 45.21 | 47.62 | 50.00 | 53.95 | 54.96 | 59.43 | 62.84 | 68.50 | 69.81 | 62.81 |
| Norfolk loam | 21.59 | 39.72 | 45.55 | 48.89 | 52.70 | 55.14 | 57.58 | 65.25 | 64.70 | 68.58 | 70.24 | 72.39 | 72.89 | 73.15 |
| Penn loam... | 12.95 | 31.75 | 36.19 | 39.72 | 42.92 | 45.46 | 48.00 | 52.47 | 54.96 | 59.94 | 64.77 | 70.48 | 72.13 | 74.40 |
| Sierra loam.. | 23.77 | 49.27 | 54.96 | 59.05 | 62.88 | 67.94 | 66.90 | 74.52 | 76.81 | * | * | | | |
| Wooster silt . | 18.08 | 40.38 | 46.99 | 50.54 | 53.97 | 56.88 | 59.69 | 63.81 | 75.21 | * | | | | |

* Top of cylinder.

## METHODS

The methods used in studying the ammonification process were of two kinds; (1) the beaker method as outlined by Lipman and Brown (108), and (2) a modification of the fresh-soil method as proposed by Brown (12). The first method was carried out in following manner:

One hundred-gram portions of the soil were placed in tumblers. Organic matter was weighed out into them and the latter mixed with the soil by means of the shaker devised by the writer and his colleague (103). If non-soluble materials were to be used these were added at the same time as the organic matter and mixed with it. $NaNO_3$, however, was added in solution. When the insoluble salts and organic matter were thoroughly mixed in the soil, water was added equivalent to 50 per cent of the water-holding capacity. The tumbler was then covered with a glass plate and incubated for 5 days in the case of sandy

and sandy loams, and 6 days for the other soils. The temperature of incubation was 20 to 22°C. unless otherwise stated. At the end of the incubation period the soil was removed to a copper flask with 250 cc. of water. A piece of paraffin and 5 to 6 gm. of MgO were added and the ammonia distilled off and titrated with N/10 HCl, alizarine sulphonate being used as the indicator.

In the fresh-soil method the difference to be noted was that the air-dry soils were first treated with sodium nitrate for different lengths of time at optimum water contents, and at the end of a given interval organic matter was mixed into the soil as before. The subsequent carrying out of the experiment was the same as previously described.

In order to conform as nearly as possible to field conditions, a series of fertilizer additions had to be worked out which would represent in a reasonably accurate degree the concentrations of fertilizers prevalent in present-day practices. If we could assume that all fertilizer was spread broadcast, we would have had no difficulty in determining the amounts of material to apply. However, somewhat over 85 per cent of the fertilizers are at the present drilled in. As a result we are confronted with a series of concentrations, interpendent upon the width of the layer of fertilizer falling from the drill spout and the number of drilled rows per acre. To illustrate this more plainly let us suppose that we are going to apply 50 pounds of sodium nitrate in planting an acre of corn. An acre would resolve itself into a square of 208 linear feet to the side. Corn is drilled in rows varying from 3 to 5 feet apart. Let us take 3 feet 9 inches as a standard. We would thus have 55 rows of corn per acre. Assuming that the fertilizer is spread to a width of 3 inches and moves to each side 3 inches more and that the total vertical movement is about 9 inches, we would have a block of soil 208 feet long 6 inches wide and 9 inches deep in which the fertilizer acts, or a volume of soil of 78 cubic feet. In a sandy loam having 15 per cent of moisture this volume would resolve itself into 66 cubic feet of actual air-dry soil. Taking an apparent specific gravity of 1.5 this volume of soil would weigh 6130 pounds and 55 such rows would weigh 337,150 pounds. Calculating that one acre of the same soil to a depth of 9 inches would weigh 3,500,000 pounds it is easily seen that our original concentration of 50 pounds has become ten times this, or 500 pounds. By the same method of reasoning smaller or larger applications would result in higher or lower concentrations. For instance, in fertilizing potatoes where 1500 pounds of a 4–8–10 fertilizer are drilled in, or in onion growing where 2000 to 4000 pounds of fertilizer are used, and in other lines of intensive market gardening, the actual concentration may run as high as 5000 to 10,000 pounds per acre It was decided, therefore, to employ amounts from 50 to 10,000 pounds of sodium nitrate per acre, hoping in this wide range to meet with all concentrations occurring in fertilizer practices.

In calculating the applications 3,500,000 pounds was taken as the weight of an acre nine inches of sandy soils, 2,700,000 for loam soils and 1,750,000 for the muck soil. In all cases except where acid phosphate was employed, chemically pure salts were used.

PART II

*Series 1. The influence of sodium nitrate upon the ammonification of dried blood*

Table 3 records the data to show the influence of $NaNO_3$ upon the ammonification of dried blood in seven types of soil. Two per cent of dried blood analyzing 12.48 per cent nitrogen was used as the ammonifiable material. The table has been subdivided into seven sections, each one of which gives the data for the action of sodium nitrate upon the ammonification of dried blood in one type of soil. The fertilizer additions are given in column 2. Duplicate determinations with averages are shown for each soil. In addition, the relative value of the various treatments, based upon a value of 100 for the check, has been caluclated.

An examination of table 3 shows one marked difference with regard to the influence of $NaNO_3$ upon the ability of the soils to ammonify dried blood. The greatest reaction experienced from the addition of sodium nitrate was in the Wooster silt loam. In this soil an application of sodium nitrate equal to 100 pounds per acre increased the ammonifying power of the soil 12 per cent and 300 pounds, 15 per cent. Larger applications, however, did not cause any corresponding increase in the ammonia accumulation. When an amount equal to 5000 pounds per acre was present a decrease in the ammonifying power of 30 per cent is to be noted, whereas twice this concentration depressed the ammonifying power just once again, or 70 per cent. An examination of table 2 shows us that this soil has a very rapid rise of capillary water, and no doubt the toxic effect of sodium nitrate would be of only short duration. Considering the crops grown on this soil and the amounts of fertilizer they generally receive, one need not have any fear that sodium nitrate will influence the ammonifying group in any other way than beneficially.

The soil evidencing the least response to additions of sodium nitrate was the Penn clay loam. A stimulative influence of 2 per cent was experienced with a salt concentration equal to 100 pounds per acre, and this same value held true even with amounts as high as 5000 pounds per acre. As much as 5 tons per acre of the salt did not diminish the activity of this soil's flora to the slightest degree below normal.

The results obtained from the action of sodium nitrate applied to the Norfolk sandy loam soil seem to indicate that sodium nitrate is not an important factor in influencing its ammonifying power with dried blood as the source of organic matter. No marked stimulative action is at hand until the high concentrations equal to 1500 to 2500 and 10,000 pounds per acre are present. With a concentration of 2500 pounds a stimulative influence is to be noted equivalent to 4 per cent above normal. Double this concentration also practically doubled the stimulation. This soil, being a typical early truck soil, must necessarily be heavily fertilized, and the fact that no harmful effects are manifested with such high concentrations is a very happy circumstance.

TABLE 3

*Influence of $NaNO_3$ upon the ammonification of dried blood in the various soils*

| SOIL PORTION | $NaNO_3$ PER ACRE | WOOSTER SILT LOAM | | | PER CENT RELATION TO CHECK | NORFOLK SANDY LOAM | | | PER CENT RELATION TO CHECK | PENN CLAY LOAM | | | PER CENT RELATION TO CHECK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mgm. N | Mgm. N | Average mgm. N | | Mgm. N | Mgm. N | Average mgm. N | | Mgm. N | Mgm. N | Average mgm. N | |
| | *pounds* | | | | | | | | | | | | |
| 1–2 | None | 98.24 | 100.50 | 99.87 | 100 | 59.87 | 64.73 | 62.30 | 100 | 72.09 | 73.87 | 72.98 | 100 |
| 3–4 | 50 | 103.67 | 103.56 | 103.61 | 103 | 60.75 | 63.98 | 62.37 | 100 | 69.42 | 70.10 | 69.76 | 95 |
| 5–6 | 100 | 115.83 | 108.70 | 112.25 | 112 | 67.39 | | 67.39 | 108 | 75.65 | 74.76 | 75.20 | 102 |
| 7–8 | 300 | 114.00 | 114.00 | 114.00 | 115 | 58.30 | 62.69 | 60.45 | 97 | 78.00 | 78.81 | 78.40 | 107 |
| 9–10 | 500 | 112.82 | 111.39 | 112.11 | 112 | 62.30 | 63.10 | 62.70 | 100 | 73.33 | 77.14 | 75.23 | 102 |
| 11–12 | 700 | 112.96 | 114.11 | 113.53 | 113 | 60.54 | 65.40 | 62.97 | 100 | 75.12 | 74.76 | 74.94 | 102 |
| 13–14 | 900 | 113.38 | 116.11 | 114.74 | 115 | 62.30 | 65.40 | 62.97 | 100 | 74.76 | 74.96 | 74.86 | 102 |
| 15–16 | 1,200 | 113.39 | 112.11 | 112.75 | 113 | 66.58 | 63.30 | 64.94 | 104 | 75.20 | 75.37 | 75.28 | 102 |
| 17–18 | 1,500 | 111.83 | 113.21 | 112.52 | 113 | 64.80 | 64.80 | 64.80 | 104 | 75.20 | 75.37 | 75.28 | 102 |
| 19–20 | 2,500 | 112.97 | 112.87 | 112.93 | 113 | 61.80 | 55.40 | 58.60 | 94 | 75.71 | 75.25 | 75.48 | 102 |
| 21–22 | 5,000 | 71.50 | 70.07 | 70.78 | 70 | 66.70 | 65.12 | 65.91 | 107 | 77.60 | 72.62 | 75.11 | 102 |
| 23–24 | 10,000 | 35.32 | 35.18 | 35.25 | 35 | 66.70 | 65.12 | 65.91 | 107 | 71.37 | 75.65 | 73.51 | 100 |

| SOIL PORTION | $NaNO_3$ PER ACRE | SIERRA SANDY LOAM | | | PER CENT RELATION TO CHECK | CARRINGTON LOAM | | | PER CENT RELATION TO CHECK |
|---|---|---|---|---|---|---|---|---|---|
| | | Mgm. N | Mgm. N | Average mgm. N | | Mgm. N | Mgm. N | Average mgm. N | |
| | *pounds* | | | | | | | | |
| 1–2 | None | 107.36 | 111.18 | 109.27 | 100 | 136.56 | 136.00 | 136.28 | 100 |
| 3–4 | 50 | 112.81 | 111.61 | 112.21 | 103 | 138.71 | 138.00 | 138.35 | 101 |
| 5–6 | 100 | 109.76 | 113.57 | 111.66 | 102 | 141.14 | 140.85 | 140.99 | 103 |
| 7–8 | 300 | 113.67 | 109.00 | 111.33 | 102 | 143.00 | 142.30 | 142.65 | 104 |
| 9–10 | 500 | 113.36 | 114.99 | 114.18 | 105 | 138.66 | 138.00 | 138.33 | 101 |
| 11–12 | 700 | 113.76 | 115.76 | 114.75 | 105 | 143.00 | 142.30 | 142.67 | 104 |
| 13–14 | 900 | 116.08 | 115.54 | 115.81 | 106 | 142.30 | 142.30 | 142.30 | 104 |
| 15–16 | 1,200 | 113.90 | 113.60 | 113.75 | 104 | 142.30 | 142.30 | 142.30 | 104 |
| 17–18 | 1,500 | 103.98 | 107.14 | 105.56 | 95 | 136.56 | 139.14 | 137.84 | 101 |
| 19–20 | 2,500 | 103.98 | 104.38 | 104.18 | 95 | 131.70 | 131.90 | 131.80 | 96 |
| 21–22 | 5,000 | 93.08 | 93.28 | 93.18 | 85 | 131.27 | 128.70 | 129.98 | 95 |
| 23–24 | 10,000 | 89.92 | 89.62 | 89.77 | 82 | 119.69 | 117.78 | 118.73 | 87 |

| SOIL PORTION | $NaNO_3$ PER ACRE | NORFOLK VERY FINE SAND | | | PER CENT RELATION TO CHECK | MUCK | | | PER CENT RELATION TO CHECK |
|---|---|---|---|---|---|---|---|---|---|
| | | Mgm. N | Mgm. N | Average mgm. N | | Mgm. N | Mgm. N | Average mgm. N | |
| | *pounds* | | | | | | | | |
| 1–2 | None | 38.80 | 38.90 | 38.85 | 100 | 87.32 | 86.33 | 86.82 | 100 |
| 3–4 | 50 | 40.87 | 40.37 | 40.62 | 104 | 87.15 | 85.79 | 86.47 | 100 |
| 5–6 | 100 | 42.94 | 43.04 | 42.95 | 111 | 86.33 | 86.00 | 86.16 | 99 |
| 7–8 | 300 | 40.43 | 41.74 | 41.08 | 108 | 85.54 | 85.00 | 85.27 | 98 |
| 9–10 | 500 | | | | | 86.15 | 87.00 | 86.57 | 100 |
| 11–12 | 700 | | | | | 84.55 | 84.55 | 84.55 | 97 |
| 13–14 | 900 | 47.90 | 48.60 | 48.75 | 124 | 86.33 | 86.90 | 86.61 | 99 |
| 15–16 | 1,200 | 47.96 | 47.96 | 47.96 | 123 | 86.33 | 88.39 | 87.38 | 101 |
| 17–18 | 1,500 | 41.85 | 39.24 | 40.54 | 107 | 86.00 | 84.00 | 85.00 | 99 |
| 19–20 | 2,500 | 34.11 | 34.88 | 34.49 | 88 | 86.33 | 86.00 | 86.17 | 99 |
| 21–22 | 5,000 | 29.43 | 30.51 | 29.97 | 77 | 84.83 | 84.50 | 84.66 | 97 |
| 23–24 | 10,000 | 23.32 | 25.00 | 24.16 | 60 | 83.63 | 84.14 | 83.88 | 96 |

The ammonifying flora of the Carrington loam differs somewhat more in its response to applications of sodium nitrate than any of the other six soils. When compared with the Wooster silt loam we experienced a gradual response to additions of the fertilizer up to where a concentration of 300 pounds per acre was at hand. From here on, as in the Wooster silt loam, no enhanced or depressed activity was manifested until a concentration of 1500 pounds per acre was supplied. This concentration depressed the activity of the ammonifiers to about normal. A fertilizer increment of 1000 pounds depressed the action about 4 per cent below normal, whereas seven times this caused a depression in the activity of the ammonifying group of about 13 per cent. The capillary rise of water in this soil is not very rapid, as will be seen in table 2. However, considering the fact that only 13 per cent depression below normal occurs with a concentration of 10,000 pounds, per acre, we may have no fear of any harmful effect of sodium nitrate on such a type of soil. In fact, with small amounts we may expect a rather marked beneficial influence to the ammonifying flora.

The Sierra sandy loam is a soil quite distinct from the other types studied. Coming as it does from a semi-arid region, the concentration of the salts in its soil solution is somewhat larger than in any of the other soils. Consequently when the action of sodium nitrate upon the ammonifying flora of this soil is compared with its action in the same type of soil from humid regions, we find high concentrations of sodium nitrate exhibiting toxic effects in the Sierra sandy loam, whereas the same concentrations under the same moisture conditions, do not cause any decreased ammonia accumulation in the Norfolk sandy loam.

A stimulative action is to be noted in this soil, however, the maximum, 6 per cent, being at hand with a concentration equivalent to 900 pounds per acre.

With the Muck soil no decisive response whatever is to be noted. The ammonifying flora is either non-responsive to nitrate fertilization or else the high absorption power of such a type of soil militates against the presence of the salt in the soil solution and its subsequent action upon the soil microorganisms. Moreover, in spite of the nature of most mucks, this specific soil has a very high concentration of available nitrates and ammonia, as will be seen by consulting table 1. Their presence would also probably inhibit the action of additional quantities of nitrates.

In all of the previous soils, nitrates in some form or other were present. It was thought that the presence of these might have some influence in regulating the reaction of additional quantities of nitrates. That is to say, if the soil was devoid of nitrates its flora would not be accustomed to their presence and fresh additions of the salt ought to give greater and an earlier reaction upon the ammonifying flora.

In order to test this out, a seventh soil, a Norfolk very fine sand was chosen. This soil had only a trace of nitrates in each 100 grams. It had, however, the biological and chemical characteristics of a true soil. It would seem from an examination of section 6 that the *a priori* assumption above made was true.

Although the duplicate determinations in some cases are not all that are to be desired, due no doubt to loses entailed in a soil of such an open texture with this quantity of ammonifiable material, a greater percentage increase is to be noted as a result of the action of $NaNO_3$ than in any of the other soils examined. The greatest activity was noted at a concentration of 900 pounds per acre. At this point an increase of 24 per cent above normal was recorded. Although exhibiting the greatest stimulation to the presence of sodium nitrate, this soil also was the most seriously influenced in its decomposition powers by larger quantities of this salt. Even though the same moisture conditions are present as are in the other sandy soils a much greater toxic action occurred to depress the activity below normal.

In all of these tests the action of sodium nitrate seems to work along definite lines. We have at first an enhanced effect followed by an action non-divergent from the maximum and later on, as the concentration increases, a depressed accumulation of ammonia. The question naturally arises as to the cause of such a phenomenon. Is it due to internal conditions, such as the composition of the material in itself, or is it due to external conditions, such as the lack of the mineral elements—phosphoric acid, potash and lime? Also, we might find an answer if we studied the action of moisture, temperature or mechanical composition of the soil upon the ammonification of dried blood as influenced by the presence of nitrate of soda. We may further find substance in the theory that perhaps the rapid multiplication of microörganisms in the process of ammonification unavoidably involves the transformation of soluble ammonia back into protein forms.

The tenability of these ideas will be taken up later in the thesis, it being only too apparent that some controlling factor is operating against a larger accumulation of ammonia when the results of the next series are considered.

*Series 2. The influence of nitrate of soda upon the ammonification of cottonseed meal*

In this series cottonseed meal was substituted for dried blood. Cottonseed meal is a substance of vegetable origin and in this connection represents the plant residues from which the soil organic matter is mainly derived more closely than dried blood, a substance of animal origin representing insect and animal remains. The experiments in this series were carried out in the same fashion as in series 1. Three per cent of cottonseed meal was used as the source of organic matter. The results are given in table 4.

An examination of table 4 shows us that the ammonification of cottonseed meal is influenced very greatly by the presence of added quantities of nitrate of soda. This seems to be true in all but two of the seven soils, viz., Sierra sandy loam and the Muck soil. In these two soils, while an enhanced effect is present, it is not very large.

In this series the soil whose ammonifying flora is the most affected is the Norfolk sandy loam. In this soil there is a gradual and marked stimulation due

TABLE 4

*Showing the influence of $NaNO_3$ upon the ammonification of cottonseed meal in the various soils*

| SOIL PORTION | $NaNO_3$ PER ACRE | CARRINGTON LOAM | | | PER CENT RELATION TO CHECK | NORFOLK SANDY LOAM | | | PER CENT RELATION TO CHECK | PENN CLAY LOAM | | | PER CENT RELATION TO CHECK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mgm. N | Mgm. N | Average mgm. N | | Mgm. N | Mgm. N | Average mgm. N | | Mgm. N | Mgm. N | Average mgm. N | |
| | *pounds* | | | | | | | | | | | | |
| 1–2 | None | 62.19 | 60.87 | 61.53 | 100 | 29.32 | 30.94 | 30.13 | 100 | 77.09 | 77.77 | 77.43 | 100 |
| 3–4 | 50 | 63.72 | 63.72 | 63.72 | 103 | 39.36 | 38.39 | 38.87 | 122 | 73.69 | 74.37 | 74.03 | 96 |
| 5–6 | 100 | 64.61 | 63.90 | 64.25 | 104 | 40.08 | 41.14 | 40.61 | 131 | 76.54 | 78.32 | 77.43 | 100 |
| 7–8 | 300 | 69.42 | 66.65 | 68.03 | 110 | 42.70 | 42.70 | 42.70 | 140 | 75.75 | 79.31 | 77.53 | 100 |
| 9–10 | 500 | 69.54 | 77.14 | 73.34 | 117 | 41.30 | 41.30 | 41.30 | 139 | 81.88 | 81.88 | 81.88 | 105 |
| 11–12 | 700 | 82.47 | 84.01 | 83.24 | 133 | 48.60 | 51.84 | 50.22 | 167 | 81.88 | 80.10 | 80.99 | 104 |
| 13–14 | 900 | 84.01 | 87.93 | 85.79 | 139 | 54.17 | 53.94 | 54.05 | 179 | 83.88 | 83.88 | 83.88 | 108 |
| 15–16 | 1,200 | 88.64 | 85.79 | 87.23 | 141 | 59.77 | 56.05 | 57.91 | 192 | 80.99 | 80.00 | 80.49 | 105 |
| 17–18 | 1,500 | 80.40 | | 80.40 | 130 | 62.20 | 55.40 | 58.80 | 195 | 86.00 | 85.14 | 85.57 | 110 |
| 19–20 | 2,500 | 86.15 | 84.55 | 85.35 | 139 | 60.20 | 59.10 | 59.65 | 198 | 84.37 | 89.50 | 86.93 | 111 |
| 21–22 | 5,000 | 85.79 | 85.79 | 85.79 | 139 | 56.60 | 57.08 | 56.84 | 188 | 89.00 | 88.33 | 88.66 | 114 |
| 23–24 | 10,000 | 87.39 | 89.00 | 88.19 | 143 | 63.13 | 61.98 | 62.54 | 207 | 88.66 | 85.44 | 87.05 | 112 |

| SOIL PORTION | $NaNO_3$ PER ACRE | SIERRA SANDY LOAM | | | PER CENT RELATION TO CHECK | WOOSTER SILT LOAM | | | PER CENT RELATION TO CHECK |
|---|---|---|---|---|---|---|---|---|---|
| | | Mgm. N | Mgm. N | Average mgm. N | | Mgm. N | Mgm. N | Average mgm. N | |
| | *pounds* | | | | | | | | |
| 1–2 | None | 83.27 | 83.30 | 83.28 | 100 | 64.99 | 65.05 | 64.77 | 100 |
| 3–4 | 50 | 82.84 | 83.64 | 83.24 | 100 | 64.91 | 63.49 | 64.20 | 100 |
| 5–6 | 100 | 83.54 | 82.05 | 82.79 | 99 | 67.21 | 70 07 | 68.64 | 106 |
| 7–8 | 300 | 85.52 | 85.52 | 85.52 | 102 | 69.92 | 70.10 | 70.06 | 108 |
| 9–10 | 500 | 85.89 | 85.80 | 85.84 | 102 | 70.88 | 71.50 | 71.19 | 109 |
| 11–12 | 700 | 85.89 | 85.29 | 85.64 | 102 | 71.50 | 71.50 | 71.50 | 110 |
| 13–14 | 900 | 85.46 | 85.29 | 85.37 | 102 | 76.97 | 77.20 | 77.08 | 118 |
| 15–16 | 1,200 | 82.84 | 84.58 | 83.71 | 100 | 80.00 | 80.98 | 80.49 | 124 |
| 17–18 | 1,500 | 85.56 | 85.46 | 85.51 | 102 | 83.16 | 83.02 | 83.08 | 128 |
| 19–20 | 2,500 | 83.34 | 84.43 | 83.88 | 100 | 87.23 | 83.22 | 85.23 | 131 |
| 21–22 | 5,000 | 83.16 | 82.62 | 82.89 | 100 | 81.22 | 82.35 | 81.78 | 126 |
| 23–24 | 10,000 | 80.11 | 79.02 | 79.58 | 95 | 67.77 | 68.94 | 68.35 | 106 |

| SOIL PORTION | $NaNO_3$ PER ACRE | NORFOLK VERY FINE SAND | | | PER CENT RELATION TO CHECK | MUCK | | | PER CENT RELATION TO CHECK |
|---|---|---|---|---|---|---|---|---|---|
| | | Mgm. N | Mgm. N | Average mgm. N | | Mgm. N | Mgm. N | Average mgm. N | |
| | *pounds* | | | | | | | | |
| 1–2 | None | 29.87 | 30.07 | 30.02 | 100 | 51.62 | 51.80 | 51.71 | 100 |
| 3–4 | 50 | 32.70 | 32.90 | 32.80 | 109 | 48.94 | 48.94 | 48.94 | 94 |
| 5–6 | 100 | 34.40 | 34.89 | 34.66 | 115 | 54.29 | 54.65 | 54.47 | 105 |
| 7–8 | 300 | 38.15 | 38.58 | 38.36 | 127 | 53.75 | 53.00 | 53.37 | 103 |
| 9–10 | 500 | | | | | 53.04 | 52.58 | 52.81 | 102 |
| 11–12 | 700 | 42.83 | 44.38 | 43.60 | 145 | 54.29 | 53.40 | 53.84 | 104 |
| 13–14 | 900 | 56.02 | 59.40 | 57.71 | 191 | 52.51 | 52.51 | 52.51 | 102 |
| 15–16 | 1,200 | 52.32 | 52.12 | 52.22 | 173 | 52.69 | 53.23 | 52.96 | 102 |
| 17–18 | 1,500 | 45.89 | 45.99 | 45.94 | 153 | 51.89 | 54.82 | 53.35 | 103 |
| 19–20 | 2,500 | 47.41 | 47.20 | 47.30 | 157 | 52.69 | 52.69 | 52.69 | 102 |
| 21–22 | 5,000 | 40.87 | 41.96 | 41.41 | 137 | 54.10 | 54.80 | 54.45 | 105 |
| 23–24 | 10,000 | 27.25 | 28.15 | 27.70 | 92 | 53.66 | 54.10 | 53.88 | 104 |

to the presence of sodium nitrate, culminating in an increase of 107 per cent above the untreated soil. With the smaller amount of fertilizer, 100 to 300 pounds per acre, there is an increase in the ammonia accumulation of from 30 to 40 per cent over no treatment. In comparing the results of this experiment with those obtained with dried blood on the same type of soil, a most astounding difference is to be seen. In the last series we did not experience an increase of over 7 per cent above normal with all the concentrations used, whereas in this case even 50 pounds per acre gave us an increased activity of over 20 per cent. It is needless to remark again that in no case was there noted any toxicity to the process of simplification of the protein molecule.

The ammonification of cottonseed meal was also greatly enhanced in the Carrington loam by the addition of $NaNO_3$. The responses to successive increments of the salt were smaller in this type of soil than in the previous one however. Whereas, in the above soil a 40 per cent increase was obtained with a concentration of 300 pounds per acre, it required several times this amount to produce the same result in this type of soil. Moreover, the maximum stimulation was only 40 per cent above normal, whereas, it was over two and one-half times this in the Norfolk sandy loam. No toxicity from the application of large amounts was apparent.

The Wooster silt loam also exhibited a greater ability to ammonify cottonseed meal in the presence of varying amounts of sodium nitrate than did dried blood. In this type of soil the maximum enhanced activity was 31 per cent above normal. The amount of sodium nitrate present in this case was 2500 pounds per acre. In this soil no enhanced effect was noted at the lowest concentration of applied salts. The reaction is not very marked until a quantity of salt equivalent to 300 or 500 pounds per acre is present. In this soil there is no toxicity present in any concentration to lower the activity of the ammonifying group below the non-treated portions. There is, however, evidence that if the concentration was increased beyond the maximum amount applied here bad effects would follow. This is indicated by the depression from the maximum, 31 per cent, to 26 per cent and 6 per cent, respectively, where 5000 and 10,000 pounds of salt were applied.

In contradistinction to the effect of sodium nitrate upon the ammonifiability of dried blood in the previous series where the Penn clay loam was used, a rather noticeable enhanced activity occurred, reaching a maximum of 14 per cent above normal with an application of $NaNO_3$ to the highest concentration. Also, appreciable responses are to be noted in this type of soil with smaller quantities. A comparison of the effect of sodium nitrate upon the ammonifying flora of this soil, with the Carrington loam, Norfolk sandy loam and Wooster silt loam shows us that it is the least affected of the four. The question arises as to the cause of such a phenomenon. Is it a question of soil flora? Are the more aerobic conditions present in the three mentioned soils such as to bring out certain types and groups of soil microörganisms, which are stimulated by applications of sodium nitrate, or has the mechanical condition of the soil

tended to adsorb the soluble nitrates thus keeping them out of the soil solution and affecting the soil organisms? Lipman and his associates have shown that applications of sodium nitrate were much more effective in a Penn loam soil that had been diluted by means of quartz sand than in the undiluted portion.

The Sierra sandy loam, as well as the Muck, although evidencing a small enhanced activity due to the presence of soluble nitrates, could not be considered as being very greatly stimulated by the presence of this salt. In the previous series where dried blood was used as the ammonifiable material the Sierra sandy loam recorded a slightly greater enhanced activity than in this series, some 4 per cent less activity being noted here. A toxic effect is also on hand at the highest concentration, being 5 per cent below the untreated. In the Muck soil a more decided stimulating action has been recorded than was present in series 1. A maximum of 5 per cent was reached with the greatest amount of applied salts. With more rational amounts stimulative actions varying from 2 to 3 per cent are to be seen. On repeating the experiment in this series in a soil devoid of nitrates a somewhat similar condition is met with, as was experienced in the previous series. The maximum enhanced effect, 91 per cent above the non-treated portion, was found at a concentration equal to 900 pounds per acre. Fifty pounds per acre increased the activity of the organisms 9 per cent; 100 pounds 15 per cent and 300 pounds 27 per cent. A depressive action is present when the concentration equaled and passed 1200 pounds per acre. This depression does not fall below the record for the untreated portion, but falls off only from the maximum enhanced effect.

Quite apparent is the difference between the action of sodium nitrate upon the ammonification of cottonseed meal and dried blood in all of the seven types of soil used. The question naturally arises as to why this is so. Our knowledge of the chemical constitution of dried blood tells us that it differs quite considerably from cottonseed meal. In the first place, analyses by the writer showed it to have approximately one-half as much total phosphoric acid and potash as cottonseed meal. Also, analyses for total carbon and nitrogen tell us that their carbon-nitrogen ratio is quite different, cottonseed meal having a much greater quantity of available energy-producing materials, i.e., carbohydrates. The writer has shown (21), as well as others, that when organic materials of different carbon-nitrogen ratios are introduced into soils, considerable changes in the microbial flora are brought out. Again, one can conceive of marked differences in the cleavage products of the two substances. Other things being equal, we should expect a greater acid residue from cottonseed meal than from dried blood. This would of course affect the standing of the various groups of soil organisms, as has been shown by Fellers (37) with soil bacteria and Kopeloff (90) with soil fungi.

Perhaps the action of sodium nitrate upon the ammonification of cottonseed meal would not be so striking if the soil were made alkaline with lime. Indicative of such a thing is the action of cottonseed meal in the Sierra sandy loam, which as will be remembered, is alkaline in reaction. As has been pre-

viously pointed out, perhaps phosphoric acid or potash is important for the action of sodium nitrate in increasing the decay of dried blood. With these thoughts in mind we shall follow the decay of dried blood and cottonseed meal in the presence of both acid phosphate and nitrate of soda, in the presence of available potash, in limed soils and in the presence of available energy.

*Series 3. The influence of dextrose upon the ammonification of dried blood*

Thinking that perhaps the lack of stimulation in the ammonification of dried blood might be due to a shortage of energy-producing materials an experiment was conducted in which energy was supplied in the form of dextrose. However, in order that we might know what influence dextrose exerted upon the ammonifying efficiency of the various soils a preliminary experiment was first made in which dextrose was added in the absence of nitrate of soda. This was carried out by the same method as before. Dextrose was added in amounts equivalent to 0.1, 0.3, 0.5, 0.7, and 1 per cent.

An examination of the data in table 5, recording the influence of dextrose upon ammonification in the various soils, shows us that there is a considerable difference with regard to the influence of dextrose upon the ammonification of dried blood in the various soils. Although the ultimate action of large quantities of dextrose causes a decreased accumulation of ammonia, as has been previously shown by Doryland (27), Lipman and Brown (112) and Hutchinson and Marr (73), in some soils small amounts of dextrose gave a stimulative action to the ammonifiers, and in others no increase above the untreated portions is to be seen. The stimulative action of dextrose in the Penn clay loam is quite marked, 0.10, 0.30 and 0.50 per cent effecting appreciable increases in ammonia production. One per cent decreased the ammonia accumulation 42 per cent. An increased ammonia accumulation was obtained with 0.10 per cent of dextrose also in the Sierra sandy loam, Norfolk sandy loam and the Muck soil. In these soils as well as in the Carrington loam and Wooster silt loam, quantities in excess of this depressed the accumulation in varying degrees. The greatest depression was found in the Wooster silt loam, followed by the Norfolk sandy loam, Carrington loam, Sierra sandy loam, Penn clay loam and Muck soil. It will also be seen from an examination of the table that there are marked differences with regard to the effects of specific amounts of carbohydrates. In other words, 0.30 per cent, 0.50 per cent or 0.70 per cent in one soil did not produce the same percentage of decrease in the other soils. It is evident then that energy-producing material will influence the ammonification of dried blood to a great extent, large amounts producing the same results, whereas smaller quantities cause other effects, not necessarily in the same direction.

The fact that energy-producing materials lowered the accumulation of ammonia from the simplification of dried blood and approached accumulative conditions present with cottonseed meal induced the writer to ascertain whether or not this factor was of importance in causing the phenomena in series 1.

In testing this out, the same methods as previously used were employed. The first series was carried out with small amounts of dextrose. Two-tenths per cent of dextrose was added to all the tumblers with 2 gm. of dried blood, and thoroughly mixed with the soil. Sodium nitrate was then added as before in amounts from 50 pounds to 10,000 pounds per acre, the moisture being brought up to 0.50 per cent of the water-holding capacity of the soil. The incubation and the analysis were exactly the same as in series 1. The soils used and the data accumulated are recorded in table 6.

TABLE 5

*Influence of various amounts of dextrose upon the ammonification of dried blood*

| SOIL PORTION | DEXTROSE | CARRINGTON LOAM | | | PER CENT RELATION TO CHECK | NORFOLK SANDY LOAM | | | PER CENT RELATION TO CHECK | PENN CLAY LOAM | | | PER CENT RELATION TO CHECK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mgm. N | Mgm. N | Average mgm. N | | Mgm. N | Mgm. N | Average mgm. N | | Mgm. N | Mgm. N | Average mgm. N | |
| | *per cent* | | | | | | | | | | | | |
| 1–2 | None | 114.24 | 113.90 | 114.07 | 100 | 46.80 | 46.63 | 46.71 | 100 | 42.50 | 42.34 | 42.21 | 100 |
| 3–4 | 0.10 | 100.74 | 103.53 | 102.13 | 90 | 47.85 | 47.89 | 47.87 | 102 | 49.50 | 51.33 | 50.46 | 119 |
| 5–6 | 0.30 | 80.74 | 88.08 | 88.41 | 77 | 45.94 | 44.90 | 45.42 | 97 | 44.71 | 45.41 | 45.06 | 105 |
| 7–8 | 0.50 | 74.82 | 74.82 | 74.82 | 65 | 36.71 | 36.54 | 36.63 | 78 | 42.45 | 43.65 | 43.05 | 102 |
| 9–10 | 0.70 | 62.98 | 66.12 | 64.50 | 56 | 30.97 | 30.27 | 30.62 | 65 | 38.28 | 38.79 | 38.53 | 91 |
| 11–12 | 1.00 | 53.90 | 53.90 | 53.90 | 47 | 21.40 | 21.40 | 21.40 | 45 | 24.70 | 24.70 | 24.70 | 58 |

| SOIL PORTION | DEXTROSE | SIERRA SANDY LOAM | | | PER CENT RELATION TO CHECK | WOOSTER SILT LOAM | | | PER CENT RELATION TO CHECK | MUCK SOIL | | | PER CENT RELATION TO CHECK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mgm. N | Mgm. N | Average mgm. N | | Mgm. N | Mgm. N | Average mgm. N | | Mgm. N | Mgm. N | Average mgm. N | |
| | *per cent* | | | | | | | | | | | | |
| 1–2 | None | 98.65 | 95.35 | 97.00 | 100 | 92.22 | 93.96 | 93.09 | 100 | 94.83 | 94.85 | 94.84 | 100 |
| 3–4 | 0.10 | 102.13 | 103.85 | 102.99 | 105 | 90.13 | 90.13 | 90.13 | 96 | 97.20 | 95.33 | 96.26 | 102 |
| 5–6 | 0.30 | 91.87 | 91.87 | 91.87 | 94 | 73.08 | 73.08 | 73.08 | 78 | 89.76 | 89.43 | 89.59 | 94 |
| 7–8 | 0.50 | 74.82 | 77.60 | 76.21 | 88 | 56.02 | 58.63 | 57.32 | 61 | 88.31 | 84.73 | 86.52 | 91 |
| 9–10 | 0.70 | 69.60 | 65.25 | 67.42 | 75 | 52.20 | 50.80 | 51.50 | 55 | 74.64 | 68.03 | 71.33 | 75 |
| 11–12 | 1.00 | 49.94 | 49.94 | 49.94 | 51 | 31.66 | 30.30 | 30.98 | 30 | 72.10 | 71.76 | 71.93 | 76 |

A comparison of this table with table 3 (series 1) shows us some striking differences with regard to the influence of sodium nitrate upon the ammonification of dried blood in the presence of available energy.

It will be remembered that in series 1 the effect of sodium nitrate upon the ammonification of dried blood was of this nature—first, an enhanced effect, followed by a reaction non-divergent from the maximum until a toxic condition is reached. However, if we look at the action of this soil when ammonifying dried blood in the presence of dextrose and sodium nitrate, we find an entirely different phenomenon. In the Wooster silt loam we experienced first a slight enhanced effect, and then not the straight line effect of the previous

series, but a decided lessened accumulation of ammonia. With larger amounts we would expect to see the toxic action again acting, and this is the case. The degree of toxicity is different, however, when compared with that in the previous series.

TABLE 6

*The influence of $NaNO_3$ upon the ammonification of dried blood in the presence of dextrose (0.2 per cent)*

| SOIL PORTION | $NaNO_3$ PER ACRE | CARRINGTON LOAM | | | PER CENT RELATION TO CHECK | NORFOLK SANDY LOAM | | | PER CENT RELATION TO CHECK | PENN CLAY LOAM | | | PER CENT RELATION TO CHECK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mgm. N | Mgm. N | Average mgm. N | | Mgm. N | Mgm. N | Average mgm. N | | Mgm. N | Mgm. N | Average mgm. N | |
| | *pounds* | | | | | | | | | | | | |
| 1–2 | None | 92.82 | 93.14 | 92.98 | 100 | 59.29 | 58.32 | 58.80 | 100 | 60.41 | 61.21 | 60.81 | 100 |
| 3–4 | 50 | 92.66 | 91.36 | 92.01 | 100 | 57.89 | 57.34 | 57.61 | 95 | 57.70 | 58.98 | 58.34 | 96 |
| 5–6 | 100 | 95.58 | 96.86 | 96.22 | 103 | 58.83 | 58.80 | 58.81 | 100 | 57.67 | | 57.67 | 95 |
| 7–8 | 300 | 93.14 | 92.98 | 93.06 | 100 | 59.61 | 59.61 | 59.61 | 101 | 56.05 | 56.00 | 56.02 | 92 |
| 9–10 | 500 | 96.86 | 97.36 | 97.11 | 104 | 62.37 | 57.43 | 59.85 | 102 | 60.41 | 59.60 | 59.54 | 98 |
| 11–12 | 700 | 96.71 | 96.55 | 96.63 | 103 | 59.77 | 59.77 | 59.77 | 102 | 56.00 | 55.08 | 55.54 | 91 |
| 13–14 | 900 | 96.85 | 97.61 | 97.23 | 104 | 62.53 | 66.09 | 64.31 | 109 | 55.56 | 58.33 | 56.94 | 93 |
| 15–16 | 1,200 | 97.84 | 96.00 | 96.92 | 103 | 63.10 | 63.50 | 63.30 | 108 | 54.92 | 56.54 | 55.73 | 90 |
| 17–18 | 1,500 | 94.60 | 94.00 | 94.30 | 101 | 59.44 | 58.80 | 59.12 | 100 | 53.10 | 52.46 | 52.78 | 86 |
| 19–20 | 2,500 | 90.88 | 90.08 | 90.48 | 97 | 62.37 | | 62.37 | 106 | 53.10 | 52.78 | 52.94 | 86 |
| 21–22 | 5,000 | 88.12 | 88.60 | 88.36 | 90 | 55.89 | 50.22 | 53.09 | 90 | 52.65 | 52.60 | 52.62 | 86 |
| 23–24 | 10,000 | 80.19 | 75.81 | 78.00 | 83 | 61.50 | 63.40 | 62.45 | 106 | 52.60 | 52.60 | 52.60 | 86 |

| SOIL PORTION | $NaNO_3$ PER ACRE | SIERRA SANDY SOAM | | | PER CENT RELATION TO CHECK | WOOSTER SILT LOAM | | | PER CENT RELATION TO CHECK |
|---|---|---|---|---|---|---|---|---|---|
| | | Mgm. N | Mgm. N | Average mgm. N | | Mgm. N | Mgm. N | Average mgm. N | |
| | *pounds* | | | | | | | | |
| 1–2 | None | 103.29 | 104.56 | 103.92 | 100 | 92.82 | 92.82 | 92.82 | 100 |
| 3–4 | 50 | 104.13 | 104.98 | 104.55 | 100 | 92.84 | | 92.84 | 100 |
| 5–6 | 100 | 109.18 | 109.66 | 109.42 | 105 | 92.84 | 92.84 | 92.84 | 100 |
| 7–8 | 300 | 101.06 | 103.68 | 102.37 | 99 | 99.14 | 92.84 | 95.99 | 103 |
| 9–10 | 500 | 106.46 | 107.27 | 106.86 | 103 | 95.41 | 96.21 | 95.81 | 103 |
| 11–12 | 700 | 104.49 | 106.27 | 105.38 | 102 | 85.05 | 85.05 | 85.05 | 92 |
| 13–14 | 900 | 110.48 | 110.80 | 110.64 | 107 | 85.05 | 81.48 | 83.26 | 89 |
| 15–16 | 1,200 | 109.20 | 111.50 | 110.35 | 107 | 82.62 | 82.62 | 82.62 | 88 |
| 17–18 | 1,500 | 107.92 | 107.10 | 107.51 | 104 | 81.00 | 81.00 | 81.00 | 87 |
| 19–20 | 2,500 | 103.68 | 103.68 | 103.68 | 100 | 81.00 | 81.00 | 81.00 | 87 |
| 21–22 | 5,000 | 83.93 | 88.90 | 88.91 | 85 | 71.28 | 71.08 | 71.17 | 75 |
| 23–24 | 10,000 | 76.24 | 77.86 | 77.05 | 75 | 46.49 | 46.97 | 46.73 | 50 |

The effect of dextrose upon the ammonification of dried blood as influenced by sodium nitrate in the Penn loam clay soil is also radically different in this series. Previously we had an almost straight line effect. Now the influencing factors cause a broken line effect, the summation of which is a decided decrease in the ammonia accumulation. The influence of dextrose alone was stimulating, that of sodium nitrate alone was not appreciable in any direction.

The algebraic sum is a depression. The most logical explanation would be that in combination these two materials influenced the multiplication of soil organisms to such an extent that consumption was greater than production of ammonia as the nitrate of soda was increased.

From an examination of the effect of these materials upon the ammonification of dried blood in the Carrington loam, one finds no apparent change from the phenomenon in series 1 until a point is reached where the toxic factor again enters in. Comparing the relation values for the three highest concentrations we find that in the series without dextrose they ran 96, 95 and 87, whereas with dextrose the same concentrations of nitrate induced the values of 97, 90 and 83. It would appear that the consumption-accumulation factor was acting again.

We have about the same condition prevailing in the Sierra sandy loam. No marked difference with regard to the combined action of these materials upon ammonification of dried blood is to be noted until high concentrations of sodium nitrate are present. As in the above soil dextrose again lessens the accumulation of ammonia at the highest concentrations of sodium nitrate.

The influence of the combined action of sodium nitrate and dextrose on the ammonification of dried blood in the Norfolk sandy loam and the Muck soil is not different from that of sodium nitrate alone upon the simplification of this material. It will be remembered that dextrose in itself was stimulating; likewise, sodium nitrate in large quantities. The combined quantities of the two do not show any stimulation to speak of over the untreated portions. Thinking, however, that too little nergy had been supplied, the series was repeated with the use of a larger amount, 0.5 per cent. The results were of the same nature as previously described.

Interpreted in terms of soil fertility, this series of experiments seems to indicate that in some soils, having an abundant supply of energy-producing materials, nitrate of soda would so influence biological activities that they would secure a considerable portion of the simplified protein, and the plants would suffer accordingly. Moreover, it seems to indicate very strongly that the lack of stimulation is not due to the absence of carbohydrate as was originally surmised.

*Series 4. The influence of sodium nitrate upon the ammonification of dried blood in combination with acid phosphate*

It will be remembered that the amount of phosphoric acid in dried blood is about one-half of that present in cottonseed meal. Thinking that nitrate of soda would stimulate the ammonification of dried blood or cottonseed meal to a greater extent if more available phosphorus was present, another series of experiments were set up, adding acid phosphate containing 14 per cent of available phosphoric acid to the soil in amounts from 10 to 250 mgm. The same dried blood and method of study were used throughout this series. A pre-

liminary experiment was first set up to determine the influence of phosphoric acid upon the ammonification of dried blood and cottonseed meal before adding the nitrate of soda, the results of which are given in tables 7 and 8. An

TABLE 7

*The influence of acid phosphate upon the ammonification of dried blood*

| SOIL PORTION | ACID PHOSPHATE | CARRINGTON LOAM | | | PER CENT RELATION TO CHECK | NORFOLK SANDY LOAM | | | PER CENT RELATION TO CHECK | PENN CLAY LOAM | | | PER CENT RELATION TO CHECK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mgm. N | Mgm. N | Average mgm. N | | Mgm. N | Mgm. N | Average mgm. N | | Mgm. N | Mgm. N | Average mgm. N | |
| | *per cent* | | | | | | | | | | | | |
| 1–2 | None | 107.53 | 108.57 | 108.05 | 100 | 49.41 | 49.75 | 49.63 | 100 | 54.45 | 54.45 | 54.45 | 100 |
| 3–4 | 0.010 | 112.05 | 116.18 | 114.12 | 105 | 57.24 | 54.63 | 55.93 | 112 | 57.42 | 57.93 | 57.67 | 106 |
| 5–6 | 0.025 | 112.57 | 115.85 | 114.20 | 105 | 58.46 | 57.82 | 58.14 | 117 | 62.64 | 61.69 | 62.17 | 112 |
| 7–8 | 0.050 | 115.71 | 117.62 | 116.66 | 108 | 62.64 | 63.51 | 63.07 | 127 | 60.90 | 59.86 | 60.38 | 110 |
| 9–10 | 0.100 | 126.32 | 123.54 | 124.93 | 115 | 67.86 | 67.86 | 67.86 | 136 | 63.33 | 64.03 | 63.68 | 117 |
| 11–12 | 0.250 | 128.76 | 128.60 | 128.68 | 119 | 86.05 | 86.05 | 86.05 | 179 | 75.60 | 72.03 | 73.81 | 135 |

| SOIL PORTION | ACID PHOSPHATE | SIERRA SANDY LOAM | | | PER CENT RELATION TO CHECK | WOOSTER SILT LOAM | | | PER CENT RELATION TO CHECK | MUCK SOIL | | | PER CENT RELATION TO CHECK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mgm. N | Mgm. N | Average mgm. N | | Mgm. N | Mgm. N | Average mgm. N | | Mgm. N | Mgm. N | Average mgm. N | |
| | *per cent* | | | | | | | | | | | | |
| 1–2 | None | 111.88 | 113.10 | 112.49 | 100 | 95.57 | 94.79 | 95.68 | 100 | 87.00 | 87.00 | 87.00 | 100 |
| 3–4 | 0.010 | 112.10 | 113.44 | 112.77 | 100 | 100.92 | 102.66 | 101.79 | 105 | 91.07 | 88.74 | 89.90 | 103 |
| 5–6 | 0.025 | 106.58 | 108.75 | 107.66 | 95 | 101.61 | 99.18 | 100.38 | 104 | 90.48 | 90.48 | 90.48 | 104 |
| 7–8 | 0.050 | 118.32 | 121.80 | 120.06 | 106 | 104.40 | 111.36 | 107.88 | 112 | 94.48 | 96.41 | 95.94 | 110 |
| 9–10 | 0.100 | 124.75 | 122.67 | 123.71 | 108 | 116.58 | 113.79 | 115.18 | 120 | 94.78 | 94.94 | 94.41 | 109 |
| 11–12 | 0.250 | 112.92 | 113.10 | 113.01 | 100 | 109.96 | 113.48 | 111.72 | 115 | 102.13 | 103.35 | 102.74 | 118 |

TABLE 8

*The influence of acid phosphate upon the ammonification of cottonseed meal*

| SOIL PORTION | ACID PHOSPHATE | CARRINGTON LOAM | | | PER CENT RELATION TO CHECK | PENN CLAY LOAM | | | PER CENT RELATION TO CHECK | SIERRA SANDY LOAM | | | PER CENT RELATION TO CHECK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mgm. N | Mgm. N | Average mgm. N | | Mgm. N | Mgm. N | Average mgm. N | | Mgm. N | Mgm. N | Average mgm. N | |
| | *per cent* | | | | | | | | | | | | |
| 1–2 | None | 51.60 | 51.20 | 51.40 | 100 | 34.40 | 34.60 | 34.50 | 100 | 72.20 | 70.10 | 71.15 | 100 |
| 3–4 | 0.010 | 53.34 | 52.40 | 52.80 | 101 | 35.00 | 35.00 | 35.00 | 100 | 73.40 | 70.20 | 71.80 | 100 |
| 5–6 | 0.025 | 54.60 | 56.60 | 55.60 | 104 | 34.40 | 34.80 | 34.60 | 100 | 69.00 | 69.60 | 69.30 | 98 |
| 7–8 | 0.050 | 52.60 | 51.00 | 51.80 | 100 | 34.40 | 35.40 | 34.90 | 100 | 76.00 | 76.00 | 76.00 | 107 |
| 9–10 | 0.100 | 60.00 | 56.20 | 58.10 | 112 | 34.40 | 34.80 | 34.60 | 100 | 72.60 | 77.20 | 74.90 | 105 |
| 11–12 | 0.250 | 61.60 | 58.40 | 60.00 | 114 | 34.40 | 34.80 | 34.60 | 100 | 68.00 | 71.00 | 69.50 | 98 |

examination of the tables shows us that in every case applications of acid phosphate increased the ammonification of dried blood. In the Norfolk sandy loam an increase of over 79 per cent is to be noted due to the highest

amount applied, 25 gm. Likewise in all of the other soils there are increases over no treatment varying from 15 per cent in the Wooster silt loam, to 18 per cent in the Muck, 19 per cent with the Carrington loam, and 35 per cent in the Penn loam. At the same concentration in the Sierra sandy loam a depressed activity from the maximum occurred. It would seem then that perhaps a lack of phosphates might be one of the factors limiting the production of ammonia in series 1. This would appear all the more reasonable when we examine the influence of acid phosphate upon the ammonification of cottonseed meal. The soils used to test the effect of cottonseed meal and acid phosphate were the Sierra sandy loam, the Penn clay loam and the Carrington loam. In these three soils the only one in which the ammonification of cottonseed meal was stimulated to any extent at all was the Carrington loam and this took place only at the higher concentrations. In no case, however, was the reaction as large as that taking place with dried blood and acid phosphate. In the Penn clay loam absolutely no increase over no treatment is to be seen. No toxicity was noted in the Sierra sandy loam at this time, as was the case with dried blood and acid phosphate. Taken by and large, the influence of acid phosphate upon the ammonification of cottonseed meal would tend to strengthen the feeling that lack of phosphates was the reason why sodium nitrate did not influence the degradation of dried blood to a greater extent.

However, in order to test the theory out another series of experiments were made. On account of the fact that acid phosphate did not stimulate the simplification of cottonseed meal, the experiment was confined solely to the influence of sodium nitrate upon the ammonification of dried blood in the presence of phosphates. Three types of soil were used, the Penn clay loam, the Sierra sandy loam and the Muck soil. The amount of acid phosphate giving the highest stimulation in the preliminary experiments was supplied to each tumbler with 2 gm. of the same dried blood. Sodium nitrate was then added in amounts equivalent to 50 to 10,000 pounds on the acre basis. The water content was made up to 50 per cent of the water-holding capacity and the contents of the tumblers incubated at 20 to 22°C. for 5 to 6 days. At the end of that time they were analyzed for ammonia as before described. In the untreated portion the ammonia accumulation in the Penn clay loam was 59.50 mgm., in the Sierra sandy loam 120.40 mgm. and in the Muck soil 96.57 mgm. No deviation from this figure was to be seen in any of the soils when sodium nitrate was added as a limiting factor. As the data are of a negative character it is not deemed advisable to include a table at this point. It would seem, then, that sodium nitrate is not aided in its action by an abundant supply of phosphates.

Perhaps, however, a smaller amount of phosphates or some other materials, such as potash would aid the action of this fertilizer.

*Series 5. The influence of potash upon the ammonification process*

In order to determine whether potash in itself is of importance for the ammonifying group, series 5 was instituted. The beaker method was used as before, with dried blood as the ammonifiable material. As potassium chloride is probably the most widely used of all the potash carriers, this salt was used in concentrations from 0.01 to 0.25 per cent. Four types of soil were used; the Sierra sandy loam, the Carrington loam, the Penn clay loam and the Muck soil. The incubation and subsequent analysis were carried out as usual.

TABLE 9

*The influence of potassium chloride upon the ammonification of dried blood*

| SOIL PORTION | KCl | CARRINGTON LOAM | | | PER CENT RELATION TO CHECK | PENN CLAY LOAM | | | PER CENT RELATION TO CHECK |
|---|---|---|---|---|---|---|---|---|---|
| | | Mgm. N | Mgm. N | Average mgm. N | | Mgm. N | Mgm. N | Average mgm. N | |
| | *per cent* | | | | | | | | |
| 1–2 | None | 126.54 | 127.42 | 126.98 | 100 | 59.96 | 60.19 | 60.07 | 100 |
| 3–4 | 0.010 | 125.85 | | 125.85 | 99 | 60.87 | 57.00 | 58.93 | 98 |
| 5–6 | 0.025 | 126.54 | 124.93 | 125.73 | 99 | 59.28 | 57.91 | 59.09 | 99 |
| 7–8 | 0.050 | 126.54 | 126.60 | 126.57 | 100 | 60.87 | 61.09 | 60.98 | 101 |
| 9–10 | 0.100 | 121.29 | 119.70 | 120.49 | 94 | 61.56 | 61.56 | 61.56 | 102 |
| 11–12 | 0.250 | 118.56 | 117.42 | 117.99 | 93 | 54.72 | 51.30 | 53.01 | 88 |

| SOIL PORTION | KCl | SIERRA SANDY LOAM | | | PER CENT RELATION TO CHECK | MUCK SOIL | | | PER CENT RELATION TO CHECK |
|---|---|---|---|---|---|---|---|---|---|
| | | Mgm. N | Mgm. N | Average mgm. N | | Mgm. N | Mgm. N | Average mgm. N | |
| | *per cent* | | | | | | | | |
| 1–2 | None | 128.30 | 124.26 | 128.26 | 100 | 100.12 | 98.49 | 99.30 | 100 |
| 3–4 | 0.010 | 131.55 | 130.41 | 130.98 | 103 | 103.50 | 103.94 | 103.67 | 104 |
| 5–6 | 0.025 | 132.24 | 131.10 | 131.67 | 104 | 98.04 | 100.87 | 99.45 | 100 |
| 7–8 | 0.050 | 133.86 | 131.58 | 132.72 | 105 | 105.56 | 105.12 | 105.34 | 105 |
| 9–10 | 0.100 | 125.85 | 123.80 | 124.82 | 98 | 103.50 | 103.28 | 103.39 | 104 |
| 11–12 | 0.250 | 93.98 | 93.98 | 93.98 | 79 | 99.18 | 99.85 | 99.51 | 100 |

The effect of KCl upon the ammonification of dried blood, as given in table 9, will be considered first. It will be seen that potassium chloride had little or questionable stimulative effect upon the cleavage of dried blood nitrogen. In the Carrington loam no stimulation at all is to be noted. With amounts present equal to 0.01 and 0.025 per cent a depression is noted in the ammonia accumulation. Likewise, in the Penn loam and Sierra sandy loam toxicity is evident at a concentration of 0.25 per cent. On the other hand, appreciable ammonia increases are to be noted as the effect of this salt in small concentrations in the California and Muck soil. This is to be expected, for the California soil is not as yet in a far enough advanced stage of decomposition to furnish all the potash needed, either for the plants or microörganisms. Muck soils are notoriously poor in total potash. Consequently, a response would

naturally be anticipated from the application of potash to these soils. The responses to potash in these two soils and the lack of any response in the other two soils cannot account for the lack of stimulation in series 1. To state the matter in other terms, we could hardly expect potash to benefit the action of sodium nitrate if it in itself cannot increase the degration of the protein molecule. Parenthetically, it may be pointed out that KCl is greatly more toxic than equal quantities of sodium nitrates.

The above work was duplicated with cottonseed meal as the source of organic matter. The data are given in table 10. In every soil KCl produced some kind of a reaction upon the ammonifying flora. In the Sierra sandy loam a decided toxic effect was produced because of the presence of all concentrations of this salt. This is in contradistinction to the effect of KCl upon the ammonification to dried blood. With the other three soils a stimulative influence is to be seen in nearly every case. The soil the most benefited seemed to be the Carrington loam, an increase of over 15 per cent above no treatment being registered at the highest concentration of salt employed. In this experiment no toxicity was noted with this soil.

TABLE 10

*The influence of potassium chloride upon the ammonification of cottonseed meal*

| SOIL PORTION | KCl | CARRINGTON LOAM | | | PER CENT RELATION TO CHECK | PENN CLAY LOAM | | | PER CENT RELATION TO CHECK |
|---|---|---|---|---|---|---|---|---|---|
| | | Mgm. N | Mgm. N | Average mgm. N | | Mgm. N | Mgm. N | Average mgm. N | |
| | *per cent* | | | | | | | | |
| 1–2 | None | 74.55 | 71.13 | 72.84 | 100 | 54.72 | 54.72 | 54.72 | 100 |
| 3–4 | 0.010 | 67.44 | 66.57 | 67.00 | 92 | 58.56 | 60.87 | 59.71 | 108 |
| 5–6 | 0.025 | 75.69 | 75.69 | 75.69 | 103 | 58.14 | 58.37 | 58.25 | 106 |
| 7–8 | 0.050 | 81.17 | 81.39 | 81.28 | 111 | 52.66 | 51.85 | 52.25 | 95 |
| 9–10 | 0.100 | 81.86 | 79.11 | 80.48 | 107 | 53.05 | 51.52 | 52.28 | 95 |
| 11–12 | 0.250 | 86.60 | 84.81 | 85.70 | 115 | 52.44 | 52.44 | 52.44 | 95 |

| SOIL PORTION | KCl | SIERRA SANDY LOAM | | | PER CENT RELATION TO CHECK | MUCK SOIL | | | PER CENT RELATION TO CHECK |
|---|---|---|---|---|---|---|---|---|---|
| | | Mgm. N | Mgm. N | Average mgm. N | | Mgm. N | Mgm. N | Average mgm. N | |
| | *per cent* | | | | | | | | |
| 1–2 | None | 86.64 | 85.50 | 86.07 | 100 | 88.79 | 88.84 | 88.61 | 100 |
| 3–4 | 0.010 | 84.36 | | 84.36 | 98 | 87.69 | 87.69 | 87.69 | 99 |
| 5–6 | 0.025 | 85.95 | 82.08 | 84.01 | 98 | 89.14 | 89.36 | 89.25 | 100 |
| 7–8 | 0.050 | 79.35 | 80.48 | 79.91 | 93 | 90.90 | 91.94 | 91.42 | 103 |
| 9–10 | 0.100 | 72.96 | 72.96 | 72.96 | 84 | 95.76 | 94.16 | 94.96 | 107 |
| 11–12 | 0.250 | 63.80 | 63.58 | 63.69 | 74 | 89.60 | 89.82 | 89.71 | 100 |

The Penn loam soil exhibited a stimulated action with small quantities of the salt. Larger quantities, however, depressed the activities of the ammonifying flora.

In the muck soil also a slight enhanced effect is present in concentrations around 0.025 per cent. However, if we remember the large stimulative action that sodium nitrate produced upon the ammonification of cottonseed meal in series 2 it does not appear that potassium could have been much of a factor. Koch (89) also has come to a similar conclusion.

Thinking that perhaps single applications did not permit satisfactory procedure in studying the influence of a material, and that a balancing up of the nutrients was needed to obtain better effects from the fertilization with sodium nitrate, another series of experiments were carried out.

*Series 6. The influence of various proportions of sodium nitrate, acid phosphate, and potassium chloride upon the ammonification of dried blood and cottonseed meal*

In preparing this series an attempt was made to include as large a number of proportions of the three fertilizing materials as possible. This was brought about by the use of the triangular diagram as used by Schreiner and Skinner (169). It has been shown by these investigators that variations in the proportions of three salts by increments of one-tenth of the total concentration will produce a series of 36 separate ratios. A graphic scheme showing the manner in which this series was handled is given in figure 1.

Each side of an equilateral triangle is divided into seven equal parts and lines drawn through each point in the division so obtained parallel to each of the other two sides of the triangle. Each of the original points and each of the intersecting lines represents a distinct and separate culture. All the cultures on the base line of the triangle have one-tenth of the total fertilizer in the form of sodium nitrate, in the line above two-tenths and so on to the top of the triangle which has eight parts of sodium nitrate. The first culture at the base line of the triangle has one-tenth of its total fertilizer concentration in the form of acid phosphate and the second culture two-tenths and so on to the opposite side of the triangle. Thus the eight cultures at the base of the triangle have from one-tenth to eight-tenths of the total fertilizer applications in the form of acid phosphate. Proceeding from the right to the left side of the triangle the partial concentration of potassium chloride in each culture increases in a similar manner as that followed by acid phosphate passing in the opposite direction. Thus the eight cultures in the first row have from one-tenth to eight-tenths of their total fertilizer concentration in the form of acid phosphate and from eight-tenths to one-tenth in the form of potassium chloride, with sodium nitrate making up the remaining concentration.

Each side of the triangular diagram may then be called an acid phosphate side, a potassium chloride side and a sodium nitrate side, respectively.

In using such a diagram it is necessary to start with some arbitrary concentration; after due deliberation a concentration of one-tenth of one per cent was chosen, this concentration being more often than not reached in fertilizing practices. The method of carrying out this experiment was as follows.

One hundred grams of soil were weighed into tumblers and organic matter weighed into them as the occasion might warrant. The three salts were then weighed into them in accordance with that already described, 36 distinct ratios and a no treatment portion being set up, the effects of the single elements themselves having been previously noted. The salts and organic matter were thoroughly mixed into the soil and moisture added equal to 50 per cent of the water-holding capacity. They were then covered with a glass plate and incubated for 6 days at 20 to 22°C. At the end of this time the cultures were analyzed for ammonia in the usual way. However, in order to overcome the time element, it taking some ten hours to complete an experiment of 74 cultures, a scheme was worked out whereby the cultures were analyzed in a definite out-of-order manner.

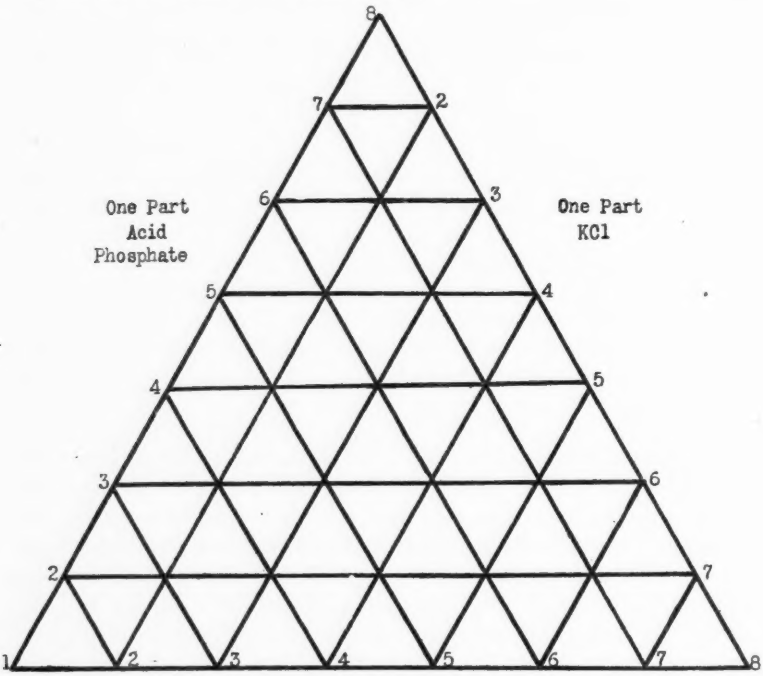


FIG. 1. DIAGRAM SHOWING THE PROPORTIONS OF THE THREE FERTILIZERS, $NaNO_3$, ACID PHOSPHATE, AND KCl.

The first experiment was carried out in the Sierra sandy loam with dried blood as the organic matter. The data accruing from this experiment are given in table 11. Column two gives the proportions in numerical values. The values of the specific ratios, the untreated soil being taken as 100 per cent, also are tabulated.

An examination of table 11 shows us that the various proportions of fertilizer carriers all affect the ammonification of dried blood somewhat differently.

Considering first those proportions which give the greatest increases over the untreated soils it will be seen that with an increase in the quantity of acid phosphate in the ratio there is, without any exception, a higher accumulation of ammonia. Comparing also the action of acid phosphate in a complete fertilizer mixture with its action when supplied singly, one finds that the

TABLE 11

*The influence of the various proportions of $NaNO_3$, acid phosphate and KCl upon the ammonification of dried blood in Sierria Sandy loam*

| SOIL PORTION | PROPORTIONS | | | ACCUMULATION OF AMMONIA | | | PER CENT RELATION TO CHECK |
|---|---|---|---|---|---|---|---|
| | $NaNO_3$ | Acid phosphate | KCl | Mgm. N | Mgm. N | Average mgm. N | |
| 73–74 | | | | 110.80 | 109.44 | 110.12 | 100 |
| 1–2 | 1 | 1 | 8 | 105.00 | 107.52 | 106.26 | 96 |
| 3–4 | 1 | 2 | 7 | 111.30 | 112.56 | 112.93 | 102 |
| 5–6 | 1 | 3 | 6 | 121.80 | 120.66 | 121.33 | 110 |
| 7–8 | 1 | 4 | 5 | 127.12 | 123.90 | 125.51 | 113 |
| 9–10 | 1 | 5 | 4 | 126.12 | | 126.12 | 114 |
| 11–12 | 1 | 6 | 3 | 131.18 | 123.48 | 127.33 | 115 |
| 13–14 | 1 | 7 | 2 | 133.80 | 135.80 | 134.80 | 122 |
| 15–16 | 1 | 8 | 1 | 140.00 | 138.60 | 139.30 | 125 |
| 17–18 | 2 | 1 | 7 | 105.56 | 113.40 | 109.48 | 99 |
| 19–20 | 2 | 2 | 6 | 116.90 | 119.00 | 117.95 | 107 |
| 21–22 | 2 | 3 | 5 | 117.60 | 117.60 | 117.60 | 107 |
| 23–24 | 2 | 4 | 4 | 125.58 | 125.58 | 125.58 | 113 |
| 25–26 | 2 | 5 | 3 | 123.20 | 127.96 | 125.53 | 113 |
| 27–28 | 2 | 6 | 2 | 131.88 | 131.88 | 131.88 | 119 |
| 29–30 | 2 | 7 | 1 | 136.88 | | 136.88 | 124 |
| 31–32 | 3 | 1 | 6 | 107.64 | 112.98 | 110.31 | 100 |
| 33–34 | 3 | 2 | 5 | 114.52 | 112.00 | 113.26 | 102 |
| 35–36 | 3 | 3 | 4 | 116.48 | 114.80 | 115.64 | 105 |
| 37–38 | 3 | 4 | 3 | 125.30 | 127.10 | 126.20 | 114 |
| 39–40 | 3 | 5 | 2 | 124.88 | 124.00 | 124.40 | 113 |
| 41–42 | 3 | 6 | 1 | 128.80 | 129.08 | 128.94 | 117 |
| 43–44 | 4 | 1 | 5 | 113.54 | 112.28 | 112.91 | 102 |
| 45–46 | 4 | 2 | 4 | 119.00 | 120.96 | 119.88 | 108 |
| 47–48 | 4 | 3 | 3 | 117.60 | 119.98 | 118.79 | 107 |
| 49–50 | 4 | 4 | 2 | 129.22 | 123.62 | 121.42 | 110 |
| 51–52 | 4 | 5 | 1 | 120.96 | 124.08 | 122.52 | 111 |
| 53–54 | 5 | 1 | 4 | 113.88 | 105.28 | 109.58 | 99 |
| 55–56 | 5 | 2 | 3 | 119.00 | 116.90 | 117.90 | 107 |
| 57–58 | 5 | 3 | 2 | 117.60 | 117.88 | 117.74 | 107 |
| 59–60 | 5 | 4 | 1 | 119.56 | 120.68 | 120.12 | 109 |
| 61–62 | 6 | 1 | 3 | 111.44 | 111.44 | 111.44 | 101 |
| 63–64 | 6 | 2 | 2 | 117.12 | 117.54 | 117.33 | 107 |
| 65–66 | 6 | 3 | 1 | 119.84 | 121.10 | 120.47 | 109 |
| 67–68 | 7 | 1 | 2 | 112.28 | 112.28 | 112.28 | 101 |
| 69–70 | 7 | 2 | 1 | 112.28 | 115.50 | 113.89 | 103 |
| 71–72 | 8 | 1 | 1 | 117.88 | 116.76 | 117.32 | 107 |

presence of sodium nitrate and potassium chloride has greatly benefited the action of this fertilizing material. In the previous series where acid phosphate alone was added to the soil in testing out its effect upon the ammonification of dried blood, it was found that a concentration of 0.10 per cent increased the simplification of the organic matter some 6 per cent. However, the same amount of fertilizer having one-half the concentration in the form of acid phosphate and the remainder in the form of sodium nitrate and potassium chloride, in various proportions, enhanced the degradation of the protein molecule some 15 per cent above the untreated soil. Even in the presence of 0.03 per cent of acid phosphate, which when applied alone stimulated activity only slightly, and 0.07 per cent of various proportions of sodium nitrate and potassium, a 10 per cent greater activity is to be noted. Applied singly, acid phosphate, at a concentration of 0.1 per cent, stimulated the ammonification of dried blood some 8 per cent; with the same concentration of acid phosphate and one part, respectively, of sodium nitrate and potassium chloride, an enhanced effect of three-fold this was experienced, although these last two materials gave very little reaction when applied singly. It will be seen that potassium chloride is toxic at the higher concentrations, which is in keeping with its action when supplied alone.

If we take the proportions where potassium chloride remains constant and acid phosphate and sodium nitrate increase and decrease simultaneously as the total concentration is approached, we find with a decrease in the acid phosphate, a corresponding decrease in the ammonia accumulation. Thus, with a ratio of 1–8–1 an enhanced activity of 25 per cent above the untreated portion occurs, whereas, when the ratio reaches 8–1–1 an activity of only 7 per cent is to be seen; with a gradual decrease between these extremes, showing without a doubt that acid phosphate is the most important material in the mixture.

In this experiment the greatest enhanced activity was manifested with a proportion of 1–8–1 and the least with 1–1–8.

Duplicating the above experiment in the Wooster silt loam, we find a similar set of conditions. The highest stimulation was again found in the 1–8–1 ratio. Making the amount of acid phosphate a constant and increasing and decreasing the sodium nitrate and potassium chloride, we note that at high concentrations of potassium chloride a toxic condition is produced again. Increasing the amounts of acid phosphate seems to stimulate the ammonification of the dried blood and the presence of both sodium nitrate and potassium chloride enhances the action of acid phosphate.

In both of these experiments neither sodium nitrate nor potassium chloride seems to increase greatly the ammonification of dried blood when present in any proportion other than in toxic quantities. Even acid phosphate added in small amounts to these proportions fails to enhance the process. On the other hand, however, acid phosphate seems to create a much greater ammonifying flora when its action is balanced by various quantities of sodium nitrate and potassium chloride.

Another experiment was run, cottonseed meal being used as the ammonifiable material. The results are not suitable for tabulation. It may be said in passing that they strongly indicate that acid phosphate and potassium chloride are of little importance for the ammonification of this material. Sodium nitrate increased the ammonification of cottonseed meal in a manner similar to its action when applied singly.

TABLE 12

*The influence of various proportions of $NaNO_3$, acid phosphate and KCl upon ammonification of dried blood in Wooster silt loam*

| SOIL PORTION | PROPORTION OF SALTS | | | AMMONIA ACCUMULATION | | | PER CENT RELATION TO CHECK |
|---|---|---|---|---|---|---|---|
| | $NaNO_3$ | Acid phosphate | KCl | Mgm. N | Mgm. N | Average mgm. N | |
| 73–74 | | | | 86.80 | 86.80 | 86.80 | 100 |
| 1–2 | 1 | 1 | 8 | 84.00 | 85.12 | 84.56 | 97 |
| 3–4 | 1 | 2 | 7 | 86.52 | 86.24 | 86.38 | 100 |
| 5–6 | 1 | 3 | 6 | 86.94 | 87.50 | 87.22 | 101 |
| 7–8 | 1 | 4 | 5 | 91.98 | 86.94 | 89.46 | 103 |
| 9–10 | 1 | 5 | 4 | 101.08 | 100.24 | 100.16 | 115 |
| 11–12 | 1 | 6 | 3 | 102.79 | | 102.79 | 117 |
| 13–14 | 1 | 7 | 2 | 105.60 | 96.88 | 101.24 | 115 |
| 15–16 | 1 | 8 | 1 | 105.60 | 102.77 | 104.18 | 120 |
| 17–18 | 2 | 1 | 7 | 86.80 | 82.46 | 84.63 | 97 |
| 19–20 | 2 | 2 | 6 | 88.20 | 87.78 | 87.99 | 102 |
| 21–22 | 2 | 3 | 5 | 91.14 | 92.12 | 91.63 | 105 |
| 23–24 | 2 | 4 | 4 | 91.00 | 89.74 | 90.37 | 104 |
| 25–26 | 2 | 5 | 3 | 93.80 | 95.48 | 94.64 | 109 |
| 27–28 | 2 | 6 | 2 | 95.34 | 96.60 | 95.97 | 110 |
| 29–30 | 2 | 7 | 1 | 105.00 | 101.92 | 103.46 | 119 |
| 31–32 | 3 | 1 | 6 | 88.48 | | 88.48 | 101 |
| 33–34 | 3 | 2 | 5 | 89.60 | 89.88 | 89.73 | 103 |
| 35–36 | 3 | 3 | 4 | 88.48 | 92.69 | 90.53 | 104 |
| 37–38 | 3 | 4 | 3 | 88.20 | 90.58 | 89.39 | 101 |
| 39–40 | 3 | 5 | 2 | 98.08 | | 98.08 | 113 |
| 41–42 | 3 | 6 | 1 | 102.84 | 106.10 | 104.47 | 120 |
| 43–44 | 4 | 1 | 5 | 75.78 | 75.00 | 75.39 | 86 |
| 45–46 | 4 | 2 | 4 | 85.82 | | 85.82 | 99 |
| 47–48 | 4 | 3 | 3 | 84.28 | 84.28 | 84.28 | 97 |
| 49–50 | 4 | 4 | 2 | 90.16 | 92.97 | 91.55 | 105 |
| 51–52 | 4 | 5 | 1 | 95.20 | 96.74 | 95.97 | 110 |
| 53–54 | 5 | 1 | 4 | 82.88 | 82.88 | 82.88 | 95 |
| 55–56 | 5 | 2 | 3 | 86.20 | 88.20 | 87.00 | 101 |
| 57–58 | 5 | 3 | 2 | 94.78 | 97.30 | 96.04 | 110 |
| 59–60 | 5 | 4 | 1 | 93.24 | | 93.24 | 107 |
| 61–62 | 6 | 1 | 3 | 89.05 | 86.38 | 87.71 | 100 |
| 63–64 | 6 | 2 | 2 | 89.32 | 87.64 | 88.48 | 104 |
| 65–66 | 6 | 3 | 1 | 89.88 | 90.30 | 90.09 | 104 |
| 67–68 | 7 | 1 | 2 | 84.00 | 84.00 | 84.00 | 96 |
| 69–70 | 7 | 2 | 1 | 88.48 | 88.48 | 88.00 | 102 |
| 71–72 | 8 | 1 | 1 | 87.22 | | 87.22 | 101 |

*Series 7. The influence of alkaline soil conditions upon the action of sodium nitrate in the ammonification of dried blood and cottonseed meal*

Perhaps the action of sodium nitrate upon the ammonification process might be different under alkaline conditions. To test this out another series of experiments were set up, the beaker method being used as previously described. In making the soil alkaline enough calcium oxide (C. P.) was added to the soil to neutralize the acidity and leave an excess present equal to 2000 pounds per acre. Although the effect of sodium nitrate in alkaline soil conditions was studied on four soil types, viz., the Carrington loam, Norfolk sandy loam, Penn clay loam and Wooster silt loam, only its effect on the two most acid soils are given.

It will be seen from an examination of tables 13 and 13a that, although lime increased the activity of the soil microörganisms, it did not create conditions favorable for nitrate of soda to stimulate the ammonification of organic matter in either of the two soils. In fact, alkaline conditions seem to diminsh the stimulating influence that sodium nitrate exhibits in the same soil, and with the same organic matter in an acid condition.

Moreover, what is very striking is the effect that an alkaline condition induces with regard to the ammonification of cottonseed meal, as influenced by various quantities of sodium nitrate.

It will be remembered that in series 2, the ammonification of cottonseed meal was very largely enhanced by the presence of $NaNO_3$. In this series, however, the influence of sodium nitrate is very meager indeed, manifesting itself only at the highest concentrations, and then only to a very slight degree. This fact is also very evident when we consult the data recording the action of sodium nitrate in the limed Carrington loam. In series 2, small amounts of sodium nitrate gave us as great an activity as ten times this amount in this experiment. In the former series the highest stimulated activity was 43 per cent over that of the untreated soil. In this series the greatest enhanced effect is not over 10 per cent above the untreated.

The toxic influence of sodium nitrate is not quite so marked in the presence of lime as can be seen by comparing the respective ammonia accumulations at the highest concentrations in both series. The effect of lime in overcoming the toxic effect of single salt applications has been previously shown by Kearney and Cameron (29), Hansteen (62), Loeb (113), and Oesterhout (131).

As an explanation of the phenomena in this series we may advance several theories. In the first place we may conceive of the combined action of sodium nitrate and calcium oxide so increasing cell division that although there was a marked degradation of the protein the ultimate accumulation would be lowered, because of the fact that it might be used as a source of food and energy.

We know also from the work of various investigators such as Faelli (34), Hall (59), Marchal (123) and Ramann (145), that acid soils may have an en-

tirely different flora from that of alkaline soils. These investigators tell us that acid soils have a much greater proportion of fungi to bacteria than alkaline soils. Brown (11), Engberding (33) and von Feilitzen (36) have taught us that

TABLE 13

*The influence of sodium nitrate upon the ammonification of dried blood in limed soils*

| SOIL PORTION | POUNDS PER ACRE $NaNO_3$ | WOOSTER SILT LOAM Ammonia Accumulation | | | PER CENT RELATION TO CHECK | CARRINGTON LOAM Ammonia Accumulation | | | PER CENT RELATION TO CHECK |
|---|---|---|---|---|---|---|---|---|---|
| | | Mgm. N | Mgm. N | Average Mgm. N | | Mgm. N | Mgm. N | Average Mgm. N | |
| 1–2 | None | 82.45 | 81.90 | 82.17 | | 139.91 | 138.89 | 139.40 | |
| 3–4 | None + lime | 104.58 | 105.28 | 104.93 | 100 | 158.10 | 158.60 | 158.35 | 100 |
| 5–6 | 100 | 100.98 | 103.19 | 102.08 | 98 | 158.10 | 159.50 | 158.80 | 100 |
| 7–8 | 300 | 104.21 | 101.66 | 102.93 | 98 | 161.16 | 159.80 | 160.48 | 101 |
| 9–10 | 500 | 106.59 | 106.27 | 106.43 | 102 | 159.80 | | 159.80 | 100 |
| 11–12 | 900 | 106.23 | 106.23 | 106.23 | 102 | 154.70 | 153.30 | 154.00 | 97 |
| 13–14 | 1,500 | 109.33 | 107.60 | 108.46 | 104 | 159.90 | 160.82 | 160.36 | 101 |
| 15–16 | 2,500 | 93.90 | 95.88 | 94.89 | 89 | 158.10 | 156.74 | 157.42 | 99 |
| 17–18 | 5,000 | 87.04 | 85.00 | 81.02 | 77 | 153.17 | 153.34 | 153.25 | 97 |
| 19–20 | 10,000 | 71.06 | 69.70 | 70.38 | 66 | 144.88 | 143.82 | 144.35 | 91 |

TABLE 13a

*The influence of sodium nitrate upon the ammonification of cottonseed meal in limed soils*

| SOIL PORTION | POUNDS PER ACRE $NaNO_3$ | CARRINGTON LOAM Ammonia Accumulation | | | PER CENT RELATION TO CHECK | WOOSTER SILT LOAM Ammonia Accumulation | | | PER CENT RELATION TO CHECK |
|---|---|---|---|---|---|---|---|---|---|
| | | Mgm. N | Mgm. N | Average Mgm. N | | Mgm. N | Mgm. N | Average Mgm. N | |
| 1–2 | None | 78.54 | 83.30 | 80.92 | | 61.54 | 57.46 | 59.50 | |
| 3–4 | None + lime | 89.44 | 90.93 | 90.18 | 100 | 69.87 | | 69.87 | 100 |
| 5–6 | 100 | 89.44 | 90.93 | 90.18 | 100 | 69.87 | 69.87 | 69.87 | 100 |
| 7–8 | 300 | 93.50 | 93.50 | 93.50 | 103 | 68.85 | 68.00 | 68.42 | 99 |
| 9–10 | 500 | 90.10 | 92.48 | 91.29 | 101 | 70.55 | 69.87 | 70.21 | 101 |
| 11–12 | 900 | 96.22 | 96.56 | 96.39 | 106 | 67.15 | 69.36 | 68.25 | 95 |
| 13–14 | 1,500 | 103.02 | 101.46 | 102.24 | 113 | 77.86 | 79.56 | 78.71 | 112 |
| 15–16 | 2,500 | 96.39 | 95.20 | 96.29 | 106 | 76.16 | 73.44 | 74.80 | 108 |
| 17–18 | 5,000 | 96.56 | 93.16 | 94.86 | 104 | 74.80 | 76.50 | 75.65 | 109 |
| 19–20 | 10,000 | 95.52 | 95.20 | 96.36 | 105 | 72.76 | 72.76 | 72.76 | 106 |

lime changes the flora by considerably increasing the numbers of microörganisms. Moreover the researches of Kopeloff (90), McLean and Wilson (124), Waksman and Cook (212), as well as the writer (21), have shown conclusively that

the addition of vegetable organic matter of various kinds markedly affects the soil flora. It was shown that cottonseed meal and like carbohydrate-carrying materials increase and alter both types and numbers to a great extent. Fungi in particular are greatly enhanced in their activity.

Perhaps, then, the combination of an acid soil and cottonseed meal has produced a flora mainly of a fungus character, stimulated in its activity by application of sodium nitrate. On the other hand, it is known that dried blood is more acceptable to bacterial activity in such a way that we can detect it by this method, or possibly not at all. If, now, we should make the soil alkaline, the activity of the fungi would be depressed and a higher proportion of bacteria would be present. Were sodium nitrate now applied one would expect a reaction similar to that in series 1, if our hypothesis is tenable. Such a phenomenon does actually take place with cottonseed meal, dried blood, calcium oxide and sodium nitrate, particularly with the former source of organic matter. It would seem that the decreased stimualtion in this series could be partially accounted for on this basis.

However, in order to gain a more definite knowledge of the action of sodium nitrate upon soil microörganisms, *per se*, another series of experiments were set up to test the effect of sodium nitrate upon some pure cultures of soil microörganisms.

### *Series 8. The effect of sodium nitrate upon the activity of some pure cultures of soil microörganisms*

In studying the influence of sodium nitrate upon the activities of pure cultures of soil organisms the method as outlined by the author (20) in another publication was employed. Briefly, it consists of inoculating sterilized soils supplied with organic matter, with pure cultures of the organisms to be tested and measuring their activity as usual by means of the ammonia accumulation.

In this series cottonseed meal was used, as the stimulation was previously obtained with this material. Ten soil fungi and six soil bacteria were tested out. The *Actinomyces*, being very weak or non-ammonifying organisms, were eliminated. [Consult Waksman and Curtis (213).]

The data showing the influence of sodium nitrate upon the ammonifying efficiency of the soil fungi tested are given in table 14. The organic matter used was cottonseed meal and the soil the Norfolk sandy loam. Sodium nitrate was supplied in amounts ranging from 10 to 250 mgm. per 100 gm. of soil.

It will be seen from an examination of table 14 that soil fungi vary considerably with regard to their response to sodium nitrate. The organism showing the greatest response to applications of this salt is *Aspergillus niger*, an application of 500 mgm. of the fertilizer stimulating its activity 64 per cent over the untreated portion. *Aspergillus bobili*, *Fusarium bullatum* and *Penicillium notatum* were all very favorably influenced by quantities of the salt up to 250 mgm. All the fungi with the exception of *Aspergillus niger* and *Aspergillus*

TABLE 14

*The influence of sodium nitrate upon the ammonifying efficiency of certain fungi*

| SOIL PORTION | $NaNO_3$ | Aspergillus niger: $NH_3$ accumulation, Mgm. N | Aspergillus niger: Mgm. N | Aspergillus niger: Average mgm. N | Per cent relation to check | Aspergillus bobili: $NH_3$ accumulation, Mgm. N | Aspergillus bobili: Mgm. N | Aspergillus bobili: Average mgm. N | Per cent relation to check | Fusarium bullatum: $NH_3$ accumulation, Mgm. N | Fusarium bullatum: Mgm. N | Fusarium bullatum: Average mgm. N | Per cent relation to check | Penicillium lividium: $NH_3$ accumulation, Mgm. N | Penicillium lividium: Mgm. N | Penicillium lividium: Average mgm. N | Per cent relation to check | Monilia sitophila: $NH_3$ accumulation, Mgm. N | Monilia sitophila: Mgm. N | Monilia sitophila: Average mgm. N | Per cent relation to check |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *per cent* | | | | | | | | | | | | | | | | | | | | |
| 1–2 | None | 23.64 | 23.00 | 23.32 | 100 | 31.10 | 30.20 | 30.65 | 100 | 63.08 | 63.08 | 63.08 | 100 | 9.35 | 9.35 | 9.35 | 100 | 51.62 | 51.60 | 51.60 | 100 |
| 3–4 | 0.010 | 22.89 | 22.19 | 22.54 | 97 | 33.67 | 32.90 | 33.28 | 108 | 62.20 | 62.40 | 62.30 | 99 | 9.65 | 9.75 | 9.70 | 101 | 52.57 | 51.00 | 51.78 | 100 |
| 5–6 | 0.025 | 24.29 | 23.80 | 24.04 | 104 | 35.30 | 36.70 | 36.00 | 116 | 69.42 | 69.40 | 69.41 | 100 | 9.24 | 9.30 | 9.27 | 100 | 53.23 | 50.00 | 51.61 | 100 |
| 7–8 | 0.050 | 26.26 | 30.15 | 28.21 | 120 | 36.60 | 36.80 | 36.70 | 117 | 73.70 | 73.71 | 73.70 | 114 | 9.25 | 9.30 | 9.27 | 100 | 53.90 | 53.90 | 53.90 | 104 |
| 9–10 | 0.100 | 30.36 | 30.00 | 30.18 | 133 | 35.89 | 35.89 | 35.89 | 116 | 73.40 | 73.80 | 73.60 | 114 | 9.25 | 9.25 | 9.25 | 100 | 56.01 | 55.07 | 55.51 | 107 |
| 11–12 | 0.250 | 33.50 | 35.40 | 34.45 | 149 | 34.33 | 34.33 | 34.33 | 111 | 72.50 | 72.80 | 72.65 | 113 | 8.30 | 8.50 | 8.50 | 90 | 53.20 | 53.20 | 53.20 | 104 |
| 13–14 | 0.500 | 39.69 | 37.20 | 38.44 | 164 | 39.68 | 39.65 | 39.65 | 127 | 51.67 | 51.60 | 51.63 | 82 | 7.65 | 7.65 | 7.65 | 82 | 45.40 | 48.66 | 47.03 | 91 |

| SOIL PORTION | $NaNO_3$ | Mucor spinosis: $NH_3$ accumulation, Mgm. N | Mucor spinosis: Mgm. N | Mucor spinosis: Average mgm. N | Per cent relation to check | Penicillium sp.: $NH_3$ accumulation, Mgm. N | Penicillium sp.: Mgm. N | Penicillium sp.: Average mgm. N | Per cent relation to check | Penicillium notatum: $NH_3$ accumulation, Mgm. N | Penicillium notatum: Mgm. N | Penicillium notatum: Average mgm. N | Per cent relation to check | Rhizopus tritica: $NH_3$ accumulation, Mgm. N | Rhizopus tritica: Mgm. N | Rhizopus tritica: Average mgm. N | Per cent relation to check | Zygorhynchus vuilleminii: $NH_3$ accumulation, Mgm. N | Zygorhynchus vuilleminii: Mgm. N | Zygorhynchus vuilleminii: Average mgm. N | Per cent relation to check |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *per cent* | | | | | | | | | | | | | | | | | | | | |
| 1–2 | None | 36.32 | 35.50 | 35.91 | 100 | 41.60 | 40.50 | 41.05 | 100 | 66.60 | 64.54 | 65.57 | 100 | 49.70 | 49.40 | 49.55 | 100 | 39.40 | 38.40 | 38.90 | 100 |
| 3–4 | 0.010 | 36.25 | 36.25 | 36.25 | 100 | 43.25 | 44.65 | 43.95 | 107 | 67.00 | 69.60 | 68.30 | 104 | 48.77 | 48.70 | 48.73 | 99 | 39.40 | 39.40 | 39.40 | 102 |
| 5–6 | 0.025 | 36.25 | 35.50 | 35.91 | 100 | 46.89 | 46.89 | 46.89 | 114 | 70.60 | 71.60 | 71.10 | 108 | 49.46 | | 49.46 | 100 | 39.40 | 39.50 | 39.45 | 102 |
| 7–8 | 0.050 | 37.40 | 36.00 | 36.70 | 101 | 45.35 | 45.65 | 45.50 | 112 | 69.00 | 70.00 | 69.50 | 105 | 49.46 | 49.46 | 49.46 | 100 | 39.00 | 38.40 | 38.90 | 100 |
| 9–10 | 0.100 | 38.40 | 38.40 | 38.40 | 107 | 45.35 | 48.90 | 47.12 | 114 | 72.60 | 73.30 | 72.95 | 111 | 50.25 | 50.25 | 50.25 | 101 | 39.50 | 39.20 | 39.35 | 102 |
| 11–12 | 0.250 | 37.20 | 37.50 | 37.35 | 106 | 42.10 | 44.10 | 43.10 | 107 | 72.60 | 70.00 | 71.80 | 109 | 48.77 | 49.40 | 49.08 | 100 | 39.50 | 39.60 | 39.55 | 102 |
| 13–14 | 0.500 | 31.33 | 31.33 | 31.33 | 89 | 39.52 | 39.10 | 39.31 | 95 | 72.60 | 70.00 | 71.80 | 109 | 44.90 | 45.00 | 44.95 | 90 | 23.38 | 24.90 | 24.24 | 62 |

*bobili* were affected adversely by additions of 0.5 per cent of sodium nitrate. *Penicillium lividum, Monilia sitophila, Mucor spinosis, Penicillium sp., Rhizopus tritica* and *Zygorhynchus Vuilleminii* were either benefited only slightly or not at all by applications of the salt. None of the organisms, however, gave anywhere nearly as much response to sodium nitrate as was evidenced in the crude culture work.

Turning our attention to the action of sodium nitrate upon the activities of some common soil bacteria we also find a stimulating effect in nearly every case. The greatest stimulation is to be seen in the experiment with *Bacillus subtilis*, and the least with *Bacillus megaterium*. In part this latter organism's activity is greatly decreased by application of sodium nitrate. A fact of importance to be noted is that sodium nitrate is much more harmful to soil bacteria in higher concentrations than to soil fugi.

Considering both groups of organisms, the fungi seem to be more favorably influenced by applications of sodium nitrate than the soil bacteria studied, a fact which would strengthen our hypothesis put forth in the last series of experiments.

In order to see just how far the accumulation-consumption theory is tenable, a new series of experiments were instituted as described in the following paragraphs.

### *Series 9. A study of ammonia accumulation versus protein simplification as a factor in ammonification studies*

In ammonification studies we use as our standard of measure the accumulation of a material readily used by microbial life. Necessarily the amount of material accumulating depends almost entirely upon the excess remaining after the microörganisms have become satiated. In fact, it has been shown, that if the energy relations are right, we may get no accumulation of ammonia at all. This may be the case in the previous series where sodium nitrate did not increase the ammonia accumulation after a certain maximum has been reached.

If we wish to eliminate this factor from our experiments, we must chose some other end point, one which will not be generally used by soil microorganisms. The bacteriologist has several such processes at his command. He may use the accumulation of carbon dioxide as proposed by Van Suchtelen (199) and Potter and Snyder (143), or he may use the accumulation of sulfate as outlined by Brown and Kellogg (13). Unfortunately, no satisfactory means for the carrying out of these two processes were at hand; consequently, some other method had to be devised. In developing such a method Kelley's (83) work on the hydrolysis of casein seemed to suggest a method whereby this assimilation factor could be eliminated. We know that casein is easily precipitated from neutral solutions by means of weak acids. This fact allows us to develop a method for the study of the ammonia production and ammonia

consumption process. In other words, should we employ this as a source of ammonificable material we could eliminate the usual end point, ammonia, and instead use as a measure of activity what has remained behind unacted upon by the microörganisms. This can be carried out at certain specified intervals and in this manner the process may be studied periodically.

TABLE 15

*The influence of sodium nitrate upon the ammonifying efficiency of soil bacteria*

| SOIL PORTION | $NaNO_3$ | BACILLUS SUBTILIS | | | PER CENT RELATION TO CHECK | BACILLUS TUMESCENS | | | PER CENT RELATION TO CHECK | BACILLUS MEGATERIUM | | | PER CENT RELATION TO CHECK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ammonia Accumulation | | | | Ammonia Accumulation | | | | Ammonia Accumulation | | | |
| | | Mgm. N | Mgm. N | Average Mgm. N | | Mgm. N | Mgm. N | Average Mgm. N | | Mgm. N | Mgm. N | Average Mgm. N | |
| | *per cent* | | | | | | | | | | | | |
| 1–2 | None | 30.50 | 31.30 | 30.90 | 100 | 11.32 | 9.02 | 10.17 | 100 | 10.22 | 9.92 | 10.07 | 100 |
| 3–4 | 0.010 | 36.26 | 36.56 | 36.41 | 117 | 10.22 | 10.64 | 10.43 | 102 | 8.62 | 9.12 | 8.87 | 88 |
| 5–6 | 0.025 | 36.11 | 36.01 | 36.06 | 116 | 10.04 | 9.92 | 9.98 | 98 | 10.24 | 9.04 | 9.64 | 96 |
| 7–8 | 0.050 | 35.48 | 35.06 | 35.27 | 113 | 12.42 | 14.40 | 13.41 | 132 | 8.84 | 8.64 | 8.74 | 87 |
| 9–10 | 0.100 | 30.40 | 29.78 | 30.09 | 99 | 13.52 | 9.62 | 11.57 | 113 | 7.04 | 8.70 | 7.87 | 78 |
| 11–12 | 0.250 | 28.20 | 26.80 | 27.50 | 89 | 7.30 | 8.04 | 7.67 | 75 | 8.44 | 9.92 | 9.18 | 91 |
| 13–14 | 0.500 | 25.90 | 26.06 | 25.98 | 84 | 5.44 | 6.34 | 5.89 | 57 | 7.22 | 8.54 | 7.88 | 78 |

| SOIL PORTION | $NaNO_3$ | PSEUDOMONAS PUTIDA | | | PER CENT RELATION TO CHECK | BACILLUS MESENTERICUS | | | PER CENT RELATION TO CHECK | BACILLUS MYCOIDES | | | PER CENT RELATION TO CHECK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ammonia Accumulation | | | | Ammonia Accumulation | | | | Ammonia Accumulation | | | |
| | | Mgm. N | Mgm. N | Average Mgm. N | | Mgm. N | Mgm. N | Average Mgm. N | | Mgm. N | Mgm. N | Average Mgm. N | |
| | *per cent* | | | | | | | | | | | | |
| 1–2 | None | 54.50 | 58.00 | 56.25 | 100 | 14.50 | 13.70 | 14.10 | 100 | 13.30 | | 13.30 | 100 |
| 3–4 | 0.010 | 59.58 | 57.68 | 58.63 | 103 | 18.03 | 17.58 | 17.80 | 111 | 14.92 | 14.52 | 14.72 | 110 |
| 5–6 | 0.025 | 52.58 | 51.62 | 52.10 | 92 | 15.00 | 14.92 | 14.96 | 105 | 14.20 | 13.92 | 14.06 | 110 |
| 7–8 | 0.050 | 59.38 | 59.36 | 59.37 | 106 | 15.58 | 14.68 | 10.13 | 70 | 14.37 | 14.80 | 14.58 | 110 |
| 9–10 | 0.100 | 64.54 | 62.00 | 63.27 | 116 | 15.40 | 12.20 | 13.80 | 92 | 12.40 | 12.17 | 12.28 | 90 |
| 11–12 | 0.250 | 54.70 | 49.00 | 51.85 | 92 | 12.92 | 12.22 | 12.57 | 80 | 10.25 | | 10.25 | 79 |
| 13–14 | 0.500 | 35.66 | 37.06 | 36.36 | 64 | 12.90 | 12.95 | 12.93 | 81 | 8.94 | 8.84 | 8.89 | 68 |

It is upon these principles that the experimental work in this series has been based. In carrying out such an experiment, however, it is necessary to start with a good quality of casein. In order to secure this, it is necessary to reprecipitate that usually found on the market. The purification of the commercial casein was brought about as follows.

Commercial casein was dissolved in warm N/10 sodium hydrate and filtered through a double thickness of cotton. The filtrate was then acidified with weak acetic acid and the

casein precipitated. The supernatent liquid was then removed, the precipitate placed on a filter paper and washed free from acid with distilled water. The precipitate was then put in a flask and digested with ether for 24 hours. At the end of this time the ether was removed by means of 95 per cent alcohol which at the same time removed any sugars, etc. The casein was then dried over sulfuric acid in a water over at 100°C.

The resulting product was not of the same nitrogen analysis as the theoretical casein molecule, but was a marked improvement over the original material.

In carrying out the experimentation proper, enough of this purified material was dissolved in dilute N/10 sodium hydrate to give 100 mgm. of nitrogen per 100 cc. of solution; 100-cc. portions were then placed in 200-cc. Erlenmeyer flasks and varying quantities of sodium nitrate added as shown in table 16. Five grams of fresh Norfolk sandy loam were used as inoculating material, the flasks thoroughly shaken and then allowed to incubate for various intervals of time. The casein was precipitated from the 100 cc. of solution by means of

TABLE 16

*The influence of $NaNO_3$ upon the ammonification and hydrolysis of casein*

| PERIOD OF INCUBATION | TREATMENTS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Series 1—No treatment | | Series 2—10 Mgm. $NaNO_3$ | | Series 3—50 Mgm. $NaNO_3$ | | Series 4—100 Mgm. $NaNO_3$ | | Series 5—500 Mgm. $NaNO_3$ | |
| | Accumulation of ammonia Mgm. N | Casein hydrolyzed Mgm. N | Accumulation of Ammonia Mgm. N | Casein hydrolyzed Mgm. N | Accumulation of Ammonia Mgm. N | Casein hydrolyzed Mgm. N | Accumulation of Ammonia Mgm. N | Casein hydrolyzed Mgm. N | Accumulation of Ammonia Mgm. N | Casein hydrolyzed Mgm. N |
| *days* | | | | | | | | | | |
| 1 | 0.90 | 6.72 | 0.96 | 4.55 | 0.75 | 4.78 | 1.26 | 5.30 | 1.35 | 5.93 |
| 2 | 2.60 | 13.95 | 3.15 | 13.04 | 4.80 | 25.80 | 4.20 | 23.95 | 3.30 | 18.35 |
| 3 | 10.00 | 21.50 | 10.55 | 20.30 | 13.75 | 49.50 | 14.70 | 52.20 | 12.20 | 56.70 |
| 4 | 20.00 | 40.75 | 21.15 | 45.90 | 26.70 | 52.40 | 30.50 | 54.40 | 25.10 | 61.65 |
| 5 | 26.00 | 46.02 | 26.40 | 43.56 | 38.70 | 52.40 | 41.45 | 55.05 | 27.79 | 61.23 |
| 7 | 42.29 | 52.03 | 47.04 | 53.32 | 51.36 | 55.29 | 50.00 | 55.52 | 30.68 | 60.78 |

1 per cent acetic acid. This was filtered off and the total nitrogen in the same determined. Likewise the filtrate was analyzed for ammonia by the magnesium oxide method. The original solution of casein was precipitated and analyzed for total nitrogen and ammonia and the results calculated on the figures so obtained. It was likewise known that casein autohydrolyses. In order to take this into consideration an experiment was set up without inoculation. Bacterial infection was eliminated by means of toluol. The figures r sulting from the autohydrolysis have also been taken into consideration in calculating the results.

In calculating the data the figures in the column headed "Accumulation of ammonia" represent the ammonia found in the filtrate after the casein has been precipitated by acetic acid. The column headed "Casein hydrolyzed" gives the amount of casein not precipitated by acetic acid after a given interval of time and represents that portion which has been acted upon by microörganisms. It will be seen by consulting table 16 that as the casein is acted upon by biological processes it goes into non-precipitable forms. That is to say,

as the interval of time increases between the first and subsequent analyses, we have less casein in solution. On the other hand, we have a corresponding increase in the hydrolyzed portion, with the formation of amino-acids and ammonia. The experiment was run in duplicate and the results given are the average of two determinations. The duplicates checked well.

It will be seen from a survey of table 16 that at the end of 24 hours very little action has taken place in the cultures. The untreated flasks have the greatest amount of casein hydrolyzed at this interval. At the end of 48 hours some marked changes have taken place in the various flasks. If we compare series 2 with the check flasks we find that no great change has taken place as a result of the presence of 10 mgm. of sodium nitrate. However, if we compare the third series with the untreated portion, we find that although the untreated portion is only slightly increased, the amount of casein hydrolyzed has increased very markedly. This is vastly out of proportion to the amount of ammonia accumulated if we conceive all the spilt ammonia as accumulating. It is very evident that something is happening which militates against the accumulation of ammonia. This is, likewise, true in the fourth and fifth series.

At the end of 72, 96, 120 and 144 hours this is again true. Where there is an increase in ammonia due to the action of sodium nitrate over that accumulating in the untreated series, the amounts of casein hydrolyzed at any given interval, as compared with the untreated portions, is much greater in all cases. Larger amounts are hydrolyzed earlier, with the higher concentration of the salt.

Of especial notice is the phenomenon in series 5. Although the ammonia accumulation is not as large as is present in any of the treated series the amount of casein hydrolyzed is much greater. At the end of 72 hours although only 12.3 mgm. of ammonia accumulated, the amount of casein hydrolyzed is greater than that hydrolyzed in the untreated portion in 168 hours. It is also greater than that hydrolyzed in series 4 in 120 hours.

It would seem then that the ammonia production-consumption theory was of great importance in ammonification studies.

We may accept the theory that sodium nitrate does actually increase biological activities to such an extent that an increased production of ammonia does not necessarily take place, although in fact the mineralization of the material has proceeded faster and to a greater extent. Such being the case, a new question arises, namely, as to the ultimate fate of this nitrogen and how soon it will again be available for plant growth. This question will be discussed later under another heading.

If, as has been pointed out, in some instances we receive an increase in the ammonia formed by applications of sodium nitrate, and in other cases no increase at all, may we not correlate this phenonenon with the increased or decreased recoveries of fertilizing material?

It has been observed that nitrate of soda when employed in extensive agri-

culture often gives returns much greater than can be accounted for by the quantity of plant-food actually supplied [Lipman (107)]. Moreover, it has been observed that the crop increase thus produced by nitrates may not be secured year after year, with ordinary applications, unless farm-yard manure or green manures be applied to offset the losses of organic matter and of nitrogen from the soil. For this reason sodium nitrate is believed by many farmers to be only a soil stimulant, hastening the depletion of soil fertility. Now, this belief is evidently due to an imperfect understanding of the observed facts, for it must be maintained that nitrate of soda is the most valuable of our nitrogenous fertilizers, and just as truly a plant-food as any incomplete fertilizer.

Where smaller returns of the nitrogen supplied as sodium nitrate are observed we may find an exhaustion, in the fact that there is some considerable conversion of applied nitrogen into protein forms for the microbial cell, resulting in a lesser quantity of nitrate being available for plant growth.

It does not follow, however, that because the influence of sodium nitrate upon soil microörganisms is being studied entirely from the nitrogen standpoint, its application does not bear an important relation to the mineral elements of plant-food, i.e., K, P, Mg, Fe, S, and silicon. Potter and Snyder (143), Ramann (140), Van Suchtelen (199), have all reported data to show the influence of fertilizers on carbon-dioxide production in soils. In the degradation of the organic matter carbon-dioxide is liberated. An increase in ammonia production necessarily results in a greater amount of carbon dioxide. Remembering that carbon dioxide is an excellent solvent and must play an important rôle in the weathering of rock fragments, we receive a hint as to the possible influence of sodium nitrate in indirectly rendering available the mineral plant-food elements of the soil. The breaking down of the soil humus by bacteria is accompanied by the formation of various organic acids which also react on the constituents of the rock fragments.

*Series 10. Is the stimulating action of sodium nitrate due to the sodium or the nitrate portion of the molecule?*

We must not leave the action of sodium nitrate upon the ammonifying group without first ascertaining whether its action is due to its sodium or its nitrate ions.

Greaves (54) in his researches says that he has good reason to believe that the anion is the most influential part of the salt, the cation being only of minor significance. His work is based upon the ammonification of dried blood. In order to see if the same thing held true with regard to sodium nitrate upon the ammonification of cottonseed meal, another series of experiments was set up, employing the four sodium salts, $NaCl$, $Na_2CO_3$, $NaNO_3$ and $Na_2SO_4$, with a constant amount of sodium, and the consequential variation of the anion. The beaker method was used and the soil was the Norfolk sandy loam. The results are given in table 17.

It is quite evident from an analysis of the table that the acid radical is of much importance in regulating the ammonification of cottonseed meal. With increases in the amounts of all four salts are obtained corresponding increases in the amount of ammonia formed. The $CO_2$ ion seems to be the most toxic of the four anions, with the cholride next, and the nitrate and sulfate in the order named. Parenthetically, it may be pointed out that in only one case, that of $Na_2CO_3$, was there any marked toxic influence present even at a concentration of 50,000 pounds per acre.

TABLE 17

*The influence of the anion upon the ammonification of cottonseed meal*

| SOIL PORTION | POUNDS PER ACRE OF SALTS | $NaNO_3$ SERIES: Ammonia accumulation | | | PER CENT RELATION TO CHECK | NaCl SERIES: Ammonia accumulation | | | PER CENT RELATION TO CHECK |
|---|---|---|---|---|---|---|---|---|---|
| | | Mgm. N | Mgm. N | Average mgm. N | | Mgm. N | Mgm. N | Average mgm. N | |
| 1–2 | None | 29.32 | 30.94 | 30.13 | 100 | 22.80 | 22.80 | 22.80 | 100 |
| 3–4 | 300 | 42.70 | 42.60 | 42.65 | 140 | 26.10 | 22.60 | 24.35 | 106 |
| 5–6 | 900 | 54.17 | 53.94 | 54.05 | 179 | 20.00 | 26.00 | 23.00 | 105 |
| 7–8 | 1,500 | 62.20 | 55.40 | 58.80 | 195 | 31.00 | | 31.00 | 136 |
| 9–10 | 2,500 | 60.20 | 59.10 | 59.65 | 198 | 33.00 | 33.00 | 33.00 | 144 |
| 11–12 | 5,000 | 56.60 | 57.08 | 56.84 | 188 | 33.80 | 33.80 | 33.80 | 145 |
| 14–14 | 10,000 | 63.13 | 61.98 | 62.54 | 207 | 38.60 | 42.40 | 40.50 | 177 |
| 15–16 | 30,000 | 69.30 | 72.40 | 70.85 | 235 | 70.60 | 69.00 | 69.80 | 306 |
| 17–18 | 50,000 | 65.20 | 68.30 | 67.20 | 229 | 51.60 | 54.00 | 52.80 | 231 |

| SOIL PORTION | POUNDS PER ACRE OF SALTS | $Na_2CO_3$ SERIES: Ammonia accumulation | | | PER CENT RELATION TO CHECK | $Na_2SO_4$ SERIES: Ammonia accumulation | | | PER CENT RELATION TO CHECK |
|---|---|---|---|---|---|---|---|---|---|
| | | Mgm. N | Mgm. N | Average mgm. N | | Mgm. N | Mgm. N | Average mgm. N | |
| 1–2 | None | 22.80 | 22.80 | 22.80 | 100 | 12.00 | 12.00 | 12.00 | 100 |
| 3–4 | 300 | 25.00 | 28.00 | 26.50 | 115 | 15.40 | | 15.40 | 128 |
| 5–6 | 900 | 58.00 | 43.00 | 50.50 | 221 | 12.00 | 12.00 | 12.00 | 100 |
| 7–8 | 1,500 | 52.40 | 52.40 | 52.40 | 227 | 8.40 | 6.80 | 7.60 | 73 |
| 9–10 | 2,500 | 64.10 | 61.60 | 62.85 | 279 | 8.80 | 8.90 | 8.85 | 83 |
| 11–12 | 5,000 | 78.40 | 64.00 | 71.20 | 312 | 7.40 | 8.80 | 8.20 | 82 |
| 13–14 | 10,000 | 65.60 | 66.00 | 65.80 | 289 | 14.00 | 10.80 | 14.40 | 180 |
| 15–16 | 30,000 | 39.60 | 41.20 | 40.40 | 177 | 20.00 | 22.80 | 21.90 | 182 |
| 17–18 | 50,000 | 12.00 | 12.60 | 12.30 | 43 | 26.60 | 31.60 | 29.10 | 242 |

## PART III

### *The influence of sodium nitrate upon the nitrification process*

Of all the nitrogen compounds yet investigated nitrates are the best, and in natural conditions probably the only nitrogenous food for the non-leguminous plants. This probability takes form from the fact that most soils are supplied with two species of soil bacteria which rapidly transform the ammonia formed by the ammonfying organisms into nitrates, the process, in the broad sense, being termed nitrification. More specifically, however, it applies to the transformation of nitrite to nitrate by *Nitrobacter*. In this text the term nitrification is used to describe the entire process of mineralization from ammonia to nitrates.

As this process is of the utmost importance for the nutrition of plants it is, therefore, of special significance to know just what the influence of additional nitrates would have upon the process.

Investigators have given us some insight into the action of sodium nitrate upon the nitrification process. For instance, Lipman and Brown (109) state that sodium nitrate markedly enhances nitrification. This also seems to be the impression one would get from the work of Sackett (159) and Wöhltmann (226). Miyake (127), using the data of Lipman and Brown (109) and Warrington (214) proves mathematically that nitrification is an auto-catalytic reaction, i.e., the presence of the end point seems to hasten the process along. On the other hand, the work of Brown and Minges (14) Deherain (25), Kelley (81), and Fred and Graul (38) seems to indicate that nitrification is not benefited, but is depressed by the presence of sodium nitrate. Warington says that nitrates do not affect the nitrification of soil humus, but that $(NH_4)_2SO_4$ does, because it becomes nitrified rather than the soil's organic matter.

It will be seen, therefore, that the opinions with regard to its action are conflicting, and it is very desirable to have further evidence on the subject.

In doing so the writer has studied the influence of sodium nitrate in five different types of soil, with three sources of nitrifiable material, the data being recorded in the following pages.

The method used in studying the process was the beaker method before described (108). Organic matter was supplied in amounts equivalent to 21 mgm. of nitrogen. Calcium carbonate was added to neutralize soil acidity and leave an excess equal to 0.02 per cent. The incubation period was 28 days at a temperature of 20°C. Moisture conditions were 50 per cent of the water-holding capacity of the soil.

The method of extracting the nitrates was that worked out by Allison (2) and the method of determining the same was that proposed by Allen (1). This exception, however, is to be noted—the quartz distilling tubes recommended by him were not used. Instead, a Kjeldahl rack with block tin tubes supplied with extra large-sized traps were employed. An average error of 0.5 cc. of N/50 acid was experienced with this modification. As

the work is comparative rather than absolute this error is of little importance, being involved in every determination.

*Series 11. The influence of sodium nitrate upon the nitrification of ammonium sulfate*

The first experiments were carried out to test the effect of sodium nitrate upon the nitrification of ammonium sulfate. Five soils were used. The fertilizer additions, nitrates accumulating and calculated data are given in table 18. It will be seen upon consulting the table that sodium nitrate seems to depress the accumulation of nitrates in every one of the soils tested. The greatest reaction seems to have taken place in the Norfolk sandy loam. In this soil applications of sodium nitrate of only 50 pounds per acre decreased the accumulation of nitrates 7 per cent. With succeeding increments a gradual depressed action is manifested being 30 per cent below normal at a concentration of 300 pounds per acre and reaching 82 per cent below normal at a concentration of 1500 pounds per acre. It seems as if the nitrification of this material is stopped entirely when 2500 pounds per acre are supplied as this type of soil.

A similar phenomenon is to be seen also in the Penn clay loam. In this soil the depression is not so large as in the previous soil. Fifty pounds per acre decreases the accumulation only 3 per cent, 500 pounds per acre 10 per cent and 1500 pounds 46 per cent below the normal nitrifying power of the soil. A small amount of nitrification, 5 per cent, was experienced at a concentration equal to 2500 pounds per acre.

In the Wooster silt loam decreceased accumulation of nitrates is not to be seen until a concentration equivalent to 500 pounds per acre is reached. From here on, however, there is a gradual decrease in the nitrate accumulation. The toxic action of sodium nitrate is not nearly as great in this soil as was the case in the Penn clay loam. Even at a concentration of 2500 pounds per acre the nitrate accumulation is only 53 per cent below normal. At double this concentration no nitrification took place, however.

Comparing the Carrington loam with these three soils we find that sodium nitrate has apparently not affected the nitrification of ammonium sulfate to any great extent. There seems to be no decrease in the amount of nitrates accumulating below normal until a concentration of 2500 pounds per acre is reached. The depression at this concentration is only 7 per cent below normal. Doubling this concentration, however, decreases the nitrifying power to about 40 per cent of normal.

The accumulation of nitrates under normal conditions in the Sierra sandy loam and the Norfolk sandy loam is practically identical. However, the action of sodium nitrate upon the nitrification of ammonium sulfate is by no means the same. In the Sierra sandy loam there is a strong indication of a stimulative action. At any rate, there is no decreased accumulation of

TABLE 18

*The influence of $NaNO_3$ upon the nitrification of ammonium sulfate*

| SOIL PORTION | SPECIAL TREATMENT | CARRINGTON LOAM Nitrate accumulation Mgm. N | CARRINGTON LOAM Nitrate accumulation Mgm. N | CARRINGTON LOAM Nitrate accumulation Ave. Mgm. N | CARRINGTON LOAM Minus no treatment | CARRINGTON LOAM Minus $NaNO_3$ added | CARRINGTON LOAM Per cent relation to check | NORFOLK SANDY LOAM Nitrate accumulation Mgm. N | NORFOLK SANDY LOAM Nitrate accumulation Mgm. N | NORFOLK SANDY LOAM Nitrate accumulation Average Mgm. N | NORFOLK SANDY LOAM Minus no treatment | NORFOLK SANDY LOAM Minus $NaNO_3$ added | NORFOLK SANDY LOAM Per cent relation to check | PENN CLAY LOAM Nitrate accumulation Mgm. N | PENN CLAY LOAM Nitrate accumulation Mgm. N | PENN CLAY LOAM Nitrate accumulation Average Mgm. N | PENN CLAY LOAM Minus no treatment | PENN CLAY LOAM Minus $NaNO_3$ added | PENN CLAY LOAM Per cent relation to check |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1–2 | Nothing | 8.60 | 8.61 | 8.60 | | | | 4.01 | 4.01 | 4.01 | | | | 7.84 | 7.94 | 7.89 | | | |
| 3–4 | 100 mgm. $(NH_4)_2SO_4$ | 23.75 | 23.85 | 23.80 | 15.20 | 15.20 | 100 | 11.85 | 11.49 | 11.85 | 7.84 | 7.84 | 100 | 23.64 | 23.67 | 23.66 | 15.77 | 15.77 | 100 |
| 5–6 | 100 mgm. $(NH_4)_2SO_4 + NaNO_3$ = 50 lbs. per acre | 24.58 | 24.68 | 24.63 | 16.03 | 15.62 | 102 | 11.66 | 11.49 | 11.57 | 7.56 | 7.31 | 93 | 23.60 | 23.60 | 23.60 | 15.71 | 15.30 | 97 |
| 7–8 | 100 mgm. $(HN_4)_2SO_4 + NaNO_2$ = 150 lbs per acre | 24.58 | 24.60 | 24.59 | 15.99 | 15.11 | 100 | 11.60 | 11.49 | 11.54 | 7.53 | 6.95 | 88 | 22.65 | 23.37 | 23.01 | 15.12 | 14.46 | 91 |
| 9–10 | 100 mgm. $(NH_4)_2SO_4 + NaNO_3$ = 300 lbs. per acre | 26.58 | 26.99 | 26.78 | 18.18 | 16.19 | 109 | 10.91 | 10.85 | 10.88 | 6.87 | 5.43 | 69 | 24.64 | 26.26 | 25.45 | 17.37 | 15.38 | 97 |
| 11–12 | 100 mgm. $(NH_4)_2SO_4 + NaNO_3$ = 500 lbs. per acre | 27.11 | 27.35 | 27.23 | 18.63 | 15.48 | 101 | 10.36 | 10.20 | 10.28 | 6.27 | 3.04 | 38 | 25.66 | 24.88 | 25.27 | 17.38 | 14.23 | 90 |
| 13–14 | 100 mgm. $(NH_4)_2SO_4 + NaNO_3$ = 700 lbs. per acre | 28.34 | 28.50 | 28.42 | 19.80 | 15.54 | 101 | 12.52 | 12.53 | 12.52 | 8.51 | 5.16 | 65 | 26.17 | 26.20 | 26.18 | 18.34 | 14.08 | 89 |
| 15–16 | 100 mgm. $(NH_4)_2SO_4 + NaNO_3$ = 900 lbs. per acre | 29.71 | 29.93 | 29.82 | 21.66 | 16.13 | 109 | 12.34 | 12.90 | 12.62 | 8.61 | 4.15 | 52 | | | | | | |
| 17–18 | 100 mgm. $(NH_4)_2SO_4 + NaNO_3$ = 1200 lbs. per acre | 30.98 | 30.90 | 30.94 | 23.76 | 15.16 | 100 | 12.80 | 12.80 | 12.80 | 8.79 | 3.14 | 40 | 33.38 | 34.63 | 34.00 | 26.11 | 14.56 | 90 |
| 19–20 | 100 mgm. $(NH_4)_2SO_4 + NaNO_3$ = 1500 lbs. per acre | 32.71 | 32.33 | 32.52 | 23.92 | 15.41 | 101 | 12.37 | 12.37 | 12.37 | 8.36 | 1.45 | 18 | | | | | | |
| 21–22 | 100 mgm. $(NH_4)_2SO_4 + NaNO_3$ = 2,500 lbs. per acre | 38.90 | 37.53 | 38.21 | 29.61 | 14.27 | 93 | 15.30 | 15.31 | 15.30 | 11.29 | 0.35 | 0.5 | 36.28 | 39.46 | 37.87 | 29.98 | +.84 | 0 |
| 23–24 | 100 mgm. $(NH_4)_2SO_4 + NaNO_3$ = 5,000 lbs. per acre | 45.51 | 46.04 | 45.77 | 37.17 | 8.03 | 62 | 23.26 | 23.26 | 23.26 | 19.30 | −2.69 | 0 | 43.22 | 43.40 | 43.31 | 35.42 | −.38 | 0 |
| 25–26 | 100 mgm. $(NH_4)_2SO_4 + NaNO_3$ = 10,000 lbs. per acre | 64.60 | 63.86 | 64.23 | 55.63 | 46.00 | 0 | 46.22 | 45.92 | 46.12 | 42.11 | −3.17 | 0 | 63.74 | 63.54 | 63.68 | 55.79 | −2.98 | 0 |

| SOIL PORTION | SPECIAL TREATMENT | SIERRIA SANDY LOAM Nitrate accumulation Mgm. N | SIERRIA SANDY LOAM Nitrate accumulation Mgm. N | SIERRIA SANDY LOAM Nitrate accumulation Average Mgm. N | SIERRIA SANDY LOAM Minus no treatment | SIERRIA SANDY LOAM Minus $NaNO_3$ added | SIERRIA SANDY LOAM Per cent relation to check | WOOSTER SILT LOAM Nitrate accumulation Mgm. N | WOOSTER SILT LOAM Nitrate accumulation Mgm. N | WOOSTER SILT LOAM Nitrate accumulation Average Mgm. N | WOOSTER SILT LOAM Minus no treatment | WOOSTER SILT LOAM Minus $NaNO_3$ added | WOOSTER SILT LOAM Per cent relation to check |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1–2 | Nothing | 5.15 | 5.15 | 5.15 | | | | 5.98 | 5.91 | 5.94 | | | |
| 3–4 | 100 mgm. $(NH_4)_2SO_4$ | 12.43 | 12.74 | 12.58 | 7.43 | 7.43 | 100 | 21.83 | 22.49 | 22.16 | 16.22 | 16.22 | 100 |
| 5–6 | 100 mgm. $(NH_4)_2 SO_4 + NaNO_3$ = 50 lbs. per acre | 13.24 | 13.57 | 13.40 | 8.05 | 7.80 | 105 | 21.83 | 22.61 | 22.22 | 16.28 | 15.85 | 98 |
| 7–8 | 100 mgm. $(NH_4)_2 SO_4 + NaNO_3$ = 150 lbs. per acre | 12.87 | | 12.87 | 7.72 | 7.14 | 94 | 23.33 | 23.33 | 23.33 | 17.39 | 16.56 | 102 |
| 9–10 | 100 mgm. $(NH_4)_2 SO_4 + NaNO_3$ = 300 lbs. per acre | 14.30 | 15.60 | 14.95 | 9.80 | 8.36 | 122 | 24.26 | 24.26 | 24.26 | 18.32 | 16.12 | 100 |
| 11–12 | 100 mgm. $(NH_4)_2 SO_4 + NaNO_3$ = 500 lbs. per acre | 15.38 | 15.11 | 15.24 | 10.09 | 7.86 | 106 | 23.38 | 23.38 | 23.38 | 17.44 | 14.41 | 89 |
| 13–14 | 100 mgm. $(NH_4)_2 SO_4 + NaNO_3$ = 700 lbs. per acre | 15.46 | 15.15 | 15.24 | 10.09 | 6.74 | 90 | 24.48 | | 24.48 | 18.54 | 14.28 | 88 |
| 15–16 | 100 mgm. $(NH_4)_2 SO_4 + NaNO_3$ = 900 lbs. per acre | 16.65 | 17.30 | 16.97 | 11.82 | 7.36 | 100 | 23.93 | 23.21 | 23.57 | 17.63 | 12.09 | 74 |
| 17–18 | 100 mgm. $(NH_4)_2 SO_4 + NaNO_3$ = 1,200 lbs. per acre | 17.22 | 17.52 | 17.37 | 12.12 | 5.22 | 70 | 25.24 | 25.68 | 25.46 | 19.52 | 11.81 | 72 |
| 19–20 | 100 mgm. $(NH_4)_2 SO_4 + NaNO_3$ = 1,500 lbs. per acre | | | | | | | 25.90 | 25.10 | 25.50 | 19.56 | 10.46 | 64 |
| 21–22 | 100 mgm. $(NH_4)_2 SO_4 + NaNO_3$ = 2,500 lbs. per acre | 18.13 | 17.64 | 17.88 | 12.73 | 1.79 | 24 | 29.44 | 27.92 | 28.68 | 22.74 | 7.59 | 47 |
| 23–24 | 100 mgm. $(NH_4)_2 SO_4 + NaNO_3$ = 5,000 lbs. per acre | 28.74 | 29.38 | 29.06 | 24.91 | 2.92 | 40 | 32.56 | 33.39 | 32.97 | 27.03 | −1.87 | 0 |
| 25–26 | 100 mgm. $(NH_4)_2 SO_4 + NaNO_3$ = 10,000 lbs. per acre | 49.97 | 49.32 | 49.61 | 44.49 | −0.79 | 0 | 59.91 | 59.91 | 59.91 | 53.97 | −4.39 | 0 |

nitrates to speak of until a concentration equivalent to 1500 pounds per acre of the salt is present. At this point the depression is about 30 per cent below normal. Beyond this point there is a rapid and pronounced decreased activity. In attempting to explain the difference in the action of the two sandy soils we must remember that the Sierra sandy loam is from a semi-arid region having a greater amount of sodium salts in its soil solution.

C. B. Lipman (104) has published his so-called antagonism theory in which he finds that the addition to soils toxic to one form of the three sodium salts, NaCl, $Na_2CO_3$ and $Na_2SO_4$, of quantities of any other of these salts will result in an improved condition of the soil flora. If these three salts can aid one another, why cannot sodium nitrate do the same thing? Let us suppose the Sierra sandy loam has one of the salts as a toxic factor. Why would not the applications of $NaNO_3$ aid in the rearrangement of the soil solution in a manner that would help the nitrifying group? In the Norfolk sandy loam, however, no abundance of so-called alkali salts could accumulate and this explanation is not tenable.

It seems also from a consideration of the data that there is a marked qualitative difference in the resistance of the different strains of the nitrifying organisms to applications of sodium nitrate. For instance, in the Wooster silt loam, having 20 per cent of moisture in the system, the depressed action at a concentration of 1500 pounds per acre is 36 per cent below normal, whereas in the Penn clay loam with 25 per cent of moisture in the system the decreased accumulation is 46 per cent below normal. In the Carrington loam, on the other hand, with the same amount of moisture no depressive action at all is to be noted. Of course, the concentration of the soil solution itself would have something to do with such a generalization, but nevertheless, differences of 50 per cent could hardly be explained away in such a manner. Correlating the phenomenon in the above experiments with actual field conditions, it would seem that the beneficial use experienced with a mixture of sodium nitrate and ammonium sulfate might be explained on the grounds that sodium nitrate decreased the mineralization of the latter until the time was opportune for its assimilation by the plant, or again, the selective action of crops for ammonia, as has been noted previously (164), might enter in, the $NaNO_3$, depressing the nitrate formation, might permit the ammonia, as such, to become assimilated.

### *Series 12. The influence of sodium nitrate upon the nitrification of dried blood nitrogen*

This series consisted of a study of the effect of sodium nitrate upon the nitrification of dried blood. The data are to be found in table 19. The action of sodium nitrate upon the nitrification of dried blood was not studied in the Norfolk sandy loam in this series.

Considering first the nitrification of the dried blood itself in this series, we

TABLE 19

*The influence of sodium nitrate upon the nitrification of dried blood*

| SOIL PORTION | SPECIAL TREATMENT | CARRINGTON LOAM | | | | | PER CENT RELATION TO CHECK | SIERRA SANDY LOAM | | | | | PER CENT RELATION TO CHECK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Nitrate accumulation | | | | | | Nitrate accumulation | | | | | |
| | | Mgm. N | Mgm. N | Average mgm. N | Minus no treatment | Minus $NaNO_3$ added | | Mgm. N | Mgm. N | Average mgm. N | Minus no treatment | Minus $NaNO_3$ added | |
| 1–2 | Nothing | 5.95 | 6.26 | 6.10 | | | | 6.13 | 6.13 | 6.13 | | | |
| 3–4 | 1731 mgm. D. B. | 21.33 | 21.49 | 21.41 | 15.31 | 15.31 | 100 | 20.35 | 19.95 | 20.15 | 14.02 | 14.02 | 100 |
| 5–6 | 1731 mgm. D. B. + $NaNO_3$ = 50 lbs. per acre | 21.49 | 22.31 | 21.90 | 15.80 | 15.37 | 100 | 19.95 | 20.13 | 20.04 | 13.91 | 13.68 | 98 |
| 7–8 | 1731 mgm. D. B. + $NaNO_3$ = 100 lbs. per acre | 22.98 | 22.63 | 22.80 | 16.70 | 15.87 | 103 | 20.04 | | 20.04 | 13.91 | 13.44 | 96 |
| 9–10 | 1731 mgm. D. B. + $NaNO_3$ = 300 lbs. per acre | 23.14 | 23.68 | 23.41 | 17.31 | 15.29 | 100 | 19.10 | 18.48 | 18.79 | 12.66 | 10.73 | 77 |
| 11–12 | 1731 mgm. D. B. + $NaNO_3$ = 500 lbs. per acre | 24.24 | 24.34 | 24.29 | 18.19 | 15.16 | 99 | 20.67 | 20.81 | 20.24 | 14.11 | 11.68 | 83 |
| 13–14 | 1731 mgm. D. B. + $NaNO_3$ = 700 lbs. per acre | 25.34 | 25.17 | 25.25 | 19.15 | 14.87 | 97 | 20.95 | 21.58 | 21.26 | 15.13 | 11.33 | 81 |
| 15–16 | 1731 mgm. D. B. + $NaNO_3$ = 900 lbs. per acre | 28.98 | 25.80 | 25.89 | 19.79 | 14.25 | 93 | 20.01 | 20.42 | 20.21 | 14.08 | 8.32 | 60 |
| 17–18 | 1731 mgm. D. B. + $NaNO_3$ = 1,200 lbs. per acre | 28.50 | 28.50 | 28.50 | 22.40 | 14.55 | 94 | | | | | | |
| 19–20 | 1731 mgm. D. B. + $NaNO_3$ = 1,500 lbs. per acre | 29.71 | 29.71 | 29.71 | 23.61 | 14.06 | 91 | 20.65 | 21.08 | 20.86 | 14.73 | 7.65 | 55 |
| 21–22 | 1731 mgm. D. B. + $NaNO_3$ = 2,500 lbs. per acre | 33.10 | 33.76 | 33.46 | 27.36 | 12.21 | 80 | 27.95 | 28.15 | 28.05 | 21.92 | 10.47 | 75 |
| 23–24 | 1731 mgm. D. B. + $NaNO_3$ = 5,000 lbs. per acre | 40.15 | 40.15 | 40.15 | 34.05 | 4.15 | 26 | 35.16 | 34.58 | 34.87 | 28.74 | 5.72 | 30 |
| 25–26 | 1731 mgm. D. B. + $NaNO_3$ = 10,000 lbs. per acre | 63.31 | 63.31 | 63.31 | 57.21 | 1.16 | 0 | 43.32 | 42.75 | 43.03 | 37.10 | 0 | 0 |

| SOIL PORTION | SPECIAL TREATMENT | PENN CLAY LOAM | | | | | PER CENT RELATION TO CHECK | WOOSTER SILT LOAM | | | | | PER CENT RELATION TO CHECK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Nitrate accumulation | | | Minus no treatment | Minus $NaNO_3$ added | | Nitrate accumulation | | | Minus no treatment | Minus $NaNO_3$ added | |
| | | Mgm. N | Mgm. N | Average mgm. N | | | | Mgm. N | Mgm. N | Average mgm. N | | | |
| 1–2 | Nothing | 8.96 | 8.96 | 8.96 | | | | 6.82 | 6.82 | 6.82 | | | |
| 3–4 | 1731 mgm. D. B. | 23.47 | 23.71 | 23.59 | 14.63 | 14.63 | 100 | 10.50 | 10.64 | 10.57 | 3.75 | 3.75 | 100 |
| 5–6 | 1731 mgm. D. B. + $NaNO_3$ = 50 lbs. per acre | 23.47 | 23.47 | 23.47 | 14.51 | 14.09 | 97 | 12.83 | 12.83 | 12.83 | 5.01 | 4.17 | 110 |
| 7–8 | 1731 mgm. D. B. + $NaNO_3$ = 100 lbs. per acre | 23.34 | 23.10 | 23.22 | 14.26 | 13.52 | 92 | 10.76 | 12.82 | 12.79 | 5.97 | 3.98 | 105 |
| 9–10 | 1731 mgm D. B. + $NaNO_3$ = 300 lbs. per acre | 24.91 | 25.15 | 25.03 | 16.07 | 14.09 | 97 | 13.17 | 13.17 | 13.17 | 6.35 | 3.20 | 84 |
| 11–12 | 1731 mgm. D. B. + $NaNO_3$ = 500 lbs. per acre | 26.12 | 27.12 | 26.67 | 17.71 | 14.57 | 99 | 13.87 | 15.04 | 14.45 | 7.63 | 3.37 | 91 |
| 13–14 | 1731 mgm. D. B. + $NaNO_3$ = 700 lbs. per acre | 27.16 | 28.00 | 27.58 | 18.62 | 14.38 | 98 | | | | | | |
| 15–16 | 1731 mgm. D. B. + $NaNO_3$ = 900 lbs. per acre | 29.95 | 26.78 | 26.86 | 17.90 | 13.80 | 87 | 12.25 | 13.38 | 12.82 | 6.00 | 1.47 | 43 |
| 17–18 | 1731 mgm. D. B. + $NaNO_3$ = 1,200 lbs. per acre | 28.16 | 30.50 | 29.37 | 20.41 | 12.41 | 84 | 16.12 | 15.92 | 16.02 | 9.20 | 2.12 | 59 |
| 19–20 | 1731 mgm. D. B. + $NaNO_3$ = 1,500 lbs. per acre | 29.00 | 31.52 | 30.26 | 21.20 | 12.05 | 82 | 16.86 | 16.68 | 16.77 | 9.95 | −0.10 | 0 |
| 21–22 | 1731 mgm. D. B. + $NaNO_3$ = 2,500 lbs. per acre | 32.65 | 31.85 | 32.24 | 23.28 | 6.40 | 42 | 19.34 | 20.56 | 19.95 | 13.13 | −2.22 | 0 |
| 23–24 | 1731 mgm. D. B. + $NaNO_3$ = 5,000 lbs. per acre | 37.09 | 37.75 | 37.42 | 28.46 | −0.34 | 0 | 32.34 | 34.12 | 33.23 | 26.41 | −2.73 | 0 |
| 25–26 | 1731 mgm. D. B. + $NaNO_3$ = 10,000 lbs. per acre | 62.26 | 61.91 | 62.18 | 53.22 | −4.94 | 0 | 61.32 | 61.32 | 61.32 | 54.90 | −3.26 | 0 |

find the Carrington loam nitrifying this material as effectively as ammonium sulfate. This was, likewise, true to a large measure with the nitrification of this material in the Penn loam soil. The Sierra sandy loam, on the other hand, nitrified dried blood to twice the extent that it did ammonium sulfate. The Wooster silt loam had very little ability to nitrify dried blood.

In the action of sodium nitrate upon the nitrification of this material we again find in every case a decreased accumulation of nitrates. In the Carrington loam this does not take place until a concentration of 500 pounds per acre is reached. From this point on, however, we note a gradual decrease in the accumulation of nitrates.

In this series the effect of sodium nitrate upon the accumulation of nitrates is not so seriously affected as was the case in the previous series. That is to say, the toxic action does not present itself in such magnitude as was the case where ammonium sulfate was the nitrifiable material.

The Wooster silt loam is the only soil in this series to exhibit an enhanced activity as a result of the presence of soluble nitrates. Because of the small amount of nitrification and the difference between parallel determinations it is even questionable whether this is actually the case, or only apparent from a mathematical standpoint.

The nitrification of dried blood in the Sierra loam is discouraged by the application of sodium nitrates in this series, in distinction to the previous effect. The Penn clay loam, likewise, showed a decrease in accumulation of nitrates as a result of the presence of sodium nitrate in this series, as was the case in the previous one.

The accumulation of nitrates as compared with the untreated soils is much greater in this series than under similar conditions in the previous series. To state the matter in other words, quantities of soluble nitrates do not seem to discourage the accumulation of nitrates from the nitrification of dried blood nitrogen as they did from ammonium sulfate. Perhaps this may be explained on the grounds of the concentration of the soil solution. When ammonium sulfate is added to the soil we have, of course, a considerable increase in the salt content of the soil solution. The concentration, i.e., osmotic concentration, is further enhanced by applications of sodium nitrate. Moreover, as ammonium sulfate rapidly changes into nitrates this ion likewise increases the osmotic pressure. The summation of these three probably was great enough seriously to discourage the nitrate building bacteria. With dried blood, on the other hand, not only is the initial concentration small but the increase in the total concentration arrives more gradually because of the slower nitrifiability of the substance. Thus the organisms have a chance to adapt themselves to their new environment.

Knowing that cottonseed meal ammonifies even more slowly than dried blood, we would expect a lesser depression in the accumulation of nitrates from high applications of sodium nitrate than from dried blood. To test this out another series was set up, the results of which are given below.

### *Series 13. The influence of sodium nitrate upon the nitrification of cottonseed meal nitrogen*

From an examination of table 20 it will be seen that all soils nitrify cottonseed meal to a lesser extent than dried blood or ammonium sulfate. The soil nitrifying this material to the greatest extent was the Norfolk sandy loam.

Considering the nitrification process in the order in which it was affected in the various soils we find that marked stimulation occurred in three of the five soils, viz, the Penn clay loam, the Sierra sandy loam, and the Wooster silt loam. The Sierra sandy loam shows a marked stimulating phenomenon in all but two cases, the maximum amount accumulating with a concentration of 700 pounds per acre. Curiously enough, there was no nitrification of cottonseed meal in this soil at a concentration of 5000 pounds, although ammonium sulfate was nitrified to an extent of about 50 per cent below normal under the same conditions.

The Carrington loam's ability to nitrify cottonseed meal was not affected to any extent by appplications of sodium nitrate until a concentration of 2500 pounds per acre was at hand. As was the case in all of the soils no nitrification took place at a concentration equivalent to 10,000 pounds per acre. It would seem also that the theory advanced in the former series was more than operating here, to allow the accumulation of relatively larger proportions of nitrates. If we consider the effect of nitrate of soda upon the nitrification of the three nitrogen-bearing materials we note that the greatest decrease in the nitrate accumulations was experienced first with ammonium sulfate as the nitrifiable material, next with dried blood and lastly with cottonseed meal. The greatest decrease is found in sandy soils, silt soils and loam soils, in the order named.

From Kelley's (83) work we are led to believe that nitrification is at its maximum at the end of two weeks' time. If such is the case we would probably expect a more decided depression in the accumulation of nitrates due to applications of sodium nitrate. In order to test this out and at the same time try to explain why sodium nitrate did not decrease the accumulation of nitrates in the Carrington silt loam, a new series of experiments were instituted designed to determine the nitrates formed from the nitrification of ammonium sulfate, dried blood and cottonseed meal at the end of 8, 16, 24, and 32 days.

### *Series 14. The influence of sodium nitrate upon the accumulation of nitrates derived from the nitrification of ammonium sulfate at various intervals of time*

In testing out the influence of time upon the accumulation of nitrates four applications of nitrate of soda were used, viz., 50, 100, 300, and 500 pounds per acre. Otherwise the method of study was identical with the previous work.

Table 21 records the data on the accumulation of nitrates from the nitrification of ammonium sulfate at different periods of time. At the end of the

TABLE 20

*The influence of sodium nitrate upon the nitrification of cottonseed meal*

| LAB. NO. | SPECIAL TREATMENT | Carrington loam: Nitrate accumulation | | | Carrington loam: Minus no treatment | Carrington loam: Minus NaNO₃ added | Carrington loam: Per cent relation to check | Norfolk sandy loam: Nitrate accumulation | | | Norfolk sandy loam: Minus no treatment | Norfolk sandy loam: Minus NaNO₃ added | Norfolk sandy loam: Per cent relation to check | Penn clay loam: Nitrate accumulation | | | Penn clay loam: Minus no treatment | Penn clay loam: Minus NaNO₃ added | Penn clay loam: Per cent relation to check |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mgm. N | Mgm. N | Average mgm. N | | | | Mgm. N | Mgm. N | Average mgm. N | | | | Mgm. N | Mgm. N | Average mgm. N | | | |
| 1–2 | Nothing | 5.95 | 6.26 | 6.10 | | | | 2.79 | 2.79 | 2.79 | | | | 8.96 | 8.96 | 8.96 | | | |
| 3–4 | 300 mgm. C. S. M | 15.96 | 16.06 | 16.01 | 9.91 | 9.91 | 100 | 14.60 | 14.31 | 14.45 | 11.66 | 11.66 | 100 | 17.61 | 16.04 | 17.22 | 8.26 | | 100 |
| 5–6 | 300 mgm. C. S. M. + $NaNO_3$ = 50 lbs. per acre | 16.31 | 16.64 | 16.47 | 10.37 | 9.94 | 100 | 13.77 | 14.59 | 14.18 | 11.39 | 11.16 | 96 | 19.22 | 18.31 | 18.76 | 9.80 | 9.37 | 113 |
| 7–8 | 300 mgm. C. S. M. + $NaNO_3$ = 100 lbs. per acre | 16.49 | 17.03 | 16.76 | 10.66 | 9.83 | 100 | 14.41 | 14.43 | 14.42 | 11.63 | 11.16 | 96 | 18.55 | 18.05 | 18.30 | 9.84 | 9.21 | 111 |
| 9–10 | 300 mgm. C. S. M. + $NaNO_3$ = 300 lbs. per acre | 18.25 | 18.14 | 18.19 | 12.09 | 10.07 | 101 | 15.80 | 15.59 | 15.69 | 12.90 | 10.97 | 94 | 19.65 | 19.71 | 19.68 | 10.72 | 8.52 | 103 |
| 11–12 | 300 mgm. C. S. M. + $NaNO_3$ = 500 lbs. per acre | 18.85 | 19.13 | 18.99 | 12.89 | 9.86 | 100 | 16.25 | 15.70 | 15.97 | 13.18 | 10.65 | 91 | 20.50 | 20.33 | 20.41 | 11.45 | 8.42 | 101 |
| 13–14 | 300 mgm. C. S. M. + $NaNO_3$ = 700 lbs. per acre | 19.49 | 19.77 | 19.63 | 13.53 | 9.27 | 94 | 17.67 | 16.08 | 16.87 | 14.08 | 10.28 | 89 | 21.23 | 20.99 | 21.11 | 12.15 | 7.87 | 95 |
| 15–16 | 300 mgm. C. S. M. + $NaNO_3$ = 900 lbs. per acre | 21.61 | 21.77 | 21.74 | 15.64 | 10.10 | 101 | 18.02 | 18.07 | 18.04 | 15.25 | 10.68 | 91 | 21.97 | 21.70 | 21.84 | 12.87 | 7.33 | 88 |
| 17–18 | 300 mgm. C. S. M. + $NaNO_3$ = 1,200 lbs. per acre | 24.03 | 24.21 | 24.12 | 18.02 | 10.27 | 102 | 19.18 | | 19.18 | 16.39 | 10.67 | 91 | 22.30 | 21.09 | 21.69 | 12.73 | 4.98 | 50 |
| 19–20 | 300 mgm. C. S. M. + $NaNO_3$ = 1,500 lbs. per acre | 25.23 | 24.83 | 25.03 | 18.93 | 9.83 | 100 | 20.25 | 20.14 | 20.69 | 17.90 | 10.82 | 92 | 20.23 | 18.49 | 19.37 | 10.41 | 1.21 | 15 |
| 21–22 | 300 mgm. C. S. M. + $NaNO_3$ = 2,500 lbs. per acre | 30.62 | 30.39 | 30.85 | 24.40 | 9.35 | 95 | 23.16 | | 23.16 | 20.37 | 8.82 | 76 | lost | lost | lost | lost | lost | lost |
| 23–24 | 300 mgm. C. S. M. + $NaNO_3$ = 5,000 lbs. per acre | 39.81 | 39.90 | 39.85 | 33.75 | 4.85 | 50 | 28.90 | 29.60 | 29.25 | 26.46 | 3.44 | 28 | 35.30 | 34.73 | 34.88 | 25.92 | −2.98 | 0 |
| 25–26 | 300 mgm. C. S. M. + $NaNO_3$ = 1,000 lbs. per acre | 63.31 | 63.31 | 63.31 | 57.70 | −1.16 | 0 | 43.59 | 44.46 | 44.02 | 41.23 | 2.79 | 21 | 63.97 | 64.16 | 64.09 | 55.13 | −3.24 | 0 |

| LAB. NO. | SPECIAL TREATMENT | Sierra sandy loam: Nitrate accumulation | | | Sierra sandy loam: Minus no treatment | Sierra sandy loam: Minus NaNO₃ added | Sierra sandy loam: Per cent relation to check | Wooster silt loam: Nitrate accumulation | | | Wooster silt loam: Minus no treatment | Wooster silt loam: Minus NaNO₃ added | Wooster silt loam: Per cent relation to check |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mgm. N | Mgm. N | Average mgm. N | | | | Mgm. N | Mgm. N | Average mgm. N | | | |
| 1–2 | Nothing | 6.22 | 6.08 | 6.15 | | | | 6.20 | 6.04 | 6.12 | | | |
| 3–4 | 300 mgm. C. S. M | 15.14 | 14.95 | 15.04 | 8.89 | 8.89 | 100 | 9.32 | 9.44 | 9.38 | 3.18 | 3.18 | 100 |
| 5–6 | 300 mgm. C. S. M. + $NaNO_3$ = 30 lbs. per acre | 15.71 | 16.11 | 15.91 | 9.76 | 9.53 | 107 | 10.04 | | 10.04 | 3.84 | 3.41 | 106 |
| 7–8 | 300 mgm. C. S. M. + $NaNO_3$ = 100 lbs. per acre | 16.22 | 16.27 | 16.29 | 10.14 | 9.67 | 108 | | | | | | |
| 9–10 | 300 mgm. C. S. M. + $NaNO_3$ = 300 lbs. per acre | 16.74 | 16.67 | 16.70 | 10.55 | 9.62 | 108 | 11.62 | 11.86 | 11.74 | 5.54 | 3.32 | 104 |
| 11–12 | 300 mgm. C. S. M. + $NaNO_3$ = 500 lbs. per acre | 18.37 | 18.36 | 18.36 | 12.21 | 9.68 | 108 | 12.42 | 12.32 | 12.37 | 6.17 | 1.89 | 60 |
| 13–14 | 300 mgm. C. S. M. + $NaNO_3$ = 700 lbs. per acre | 20.02 | 20.48 | 20.25 | 14.10 | 10.30 | 115 | 10.84 | 10.76 | 10.80 | 4.60 | 1.57 | 49 |
| 15–16 | 300 mgm. C. S. M. + $NaNO_3$ = 900 lbs. per acre | 20.60 | 19.76 | 20.18 | 14.03 | 9.46 | 106 | 11.90 | 11.90 | 11.90 | 5.70 | 0.14 | |
| 17–18 | 300 mgm. C. S. M. + $NaNO_3$ = 1,200 lbs. per acre | 21.59 | 21.05 | 21.32 | 15.17 | 9.45 | 106 | 14.92 | 14.98 | 14.95 | 8.75 | 1.00 | 31 |
| 19–20 | 300 mgm. C. S. M. + $NaNO_3$ = 1,500 lbs. per acre | 22.54 | | 22.54 | 16.39 | 9.29 | 104 | 15.78 | 15.78 | 15.78 | 9.58 | 0.48 | 15 |
| 21–22 | 300 mgm. C .S. M. + $NaNO_3$ = 2,500 lbs. per acre | 26.64 | 26.51 | 26.57 | 20.42 | 8.87 | 100 | 18.70 | 19.30 | 19.00 | 12.80 | −2.35 | 0 |
| 23–24 | 300 mgm. C. S. M. + $NaNO_3$ = 5,000 lbs. per acre | 36.20 | 36.23 | 36.21 | 30.06 | 7.14 | 81 | 32.64 | 32.96 | 32.80 | 26.68 | −2.22 | 0 |
| 25–26 | 300 mgm. C. S. M. + $NaNO_3$ = 1,000 lbs. per acre | 43.51 | 44.03 | 43.77 | 37.62 | −1.06 | 0 | 61.80 | 61.80 | 61.80 | 61.80 | −3.49 | 0 |

TABLE 21

*The influence of sodium nitrate upon the nitrification of ammonium sulfate at various intervals*

| LAB. NO. | SPECIAL TREATMENT | 8 DAYS $NO_3$ accumulation Mgm. N | 8 DAYS $NO_3$ accumulation Mgm. N | 8 DAYS $NO_3$ accumulation Average Mgm. N | MINUS NO TREATMENT | MINUS $NaNO_3$ ADDED | PER CENT RELATION TO CHECK | 16 DAYS $NO_3$ accumulation Mgm. N | 16 DAYS $NO_3$ accumulation Mgm. N | 16 DAYS $NO_3$ accumulation Average Mgm. N | MINUS NO TREATMENT | MINUS $NaNO_3$ ADDED | PER CENT RELATION TO CHECK | 24 DAYS $NO_3$ accumulation Mgm. N | 24 DAYS $NO_3$ accumulation Mgm. N | 24 DAYS $NO_3$ accumulation Average Mgm. N | MINUS NO TREATMENT | MINUS $NaNO_3$ ADDED | PER CENT RELATION TO CHECK | 32 DAYS $NO_3$ accumulation Mgm. N | 32 DAYS $NO_3$ accumulation Mgm. N | 32 DAYS $NO_3$ accumulation Average Mgm. N | MINUS NO TREATMENT | MINUS $NaNO_3$ ADDED | PER CENT RELATION TO CHECK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1–2 | Nothing | 6.67 | 6.87 | 6.77 | | | | 7.92 | 7.56 | 7.73 | | | | 8.38 | 8.30 | 8.34 | | | | 8.59 | 8.55 | 8.57 | | | |
| 3–4 | 100 mgm. $(NH_4)_2SO_4$ | 5.78 | 5.69 | 5.74 | −1.03 | | 100 | 13.56 | 13.96 | 13.76 | 6.03 | 6.03 | 100 | 23.12 | 23.39 | 23.25 | 14.91 | | 100 | 23.75 | 23.85 | 23.80 | 15.20 | 15.20 | 100 |
| 5–6 | 100 mgm. $(NH_4)_2SO_4$ + $NaNO_3$ = 50 pounds per acre | 6.22 | 6.37 | 6.29 | −0.48 | −0.89 | 114 | 13.62 | 14.01 | 13.86 | 6.13 | 5.72 | 94 | 23.81 | 23.81 | 23.81 | 15.47 | 15.06 | 102 | 24.56 | 24.68 | 24.63 | 16.06 | 15.65 | 102 |
| 7–8 | 100 mgm. $(NH_4)_2SO_4$ + $NaNO_3$ = 100 pounds per acre | 6.37 | 6.10 | 6.24 | −0.53 | −1.27 | 0 | 14.04 | | 14.04 | 6.71 | 5.87 | 95 | 23.93 | 23.93 | 23.93 | 15.59 | 14.75 | 99 | 24.58 | 24.60 | 24.59 | 16.02 | 16.18 | 100 |
| 9–10 | 100 mgm. $(NH_4)_2SO_4$ + $NaNO_3$ = 300 pounds per acre | 7.50 | 7.53 | 7.52 | +0.73 | +0.73 | 173 | 13.56 | 13.50 | 13.53 | 6.80 | 4.81 | 79 | 23.54 | 23.45 | 23.49 | 15.15 | 13.16 | 89 | 26.58 | 26.99 | 26.78 | 18.13 | 16.14 | 106 |
| 11–12 | 100 mgm. $(NH_4)_2SO_4$ + $NaNO_3$ = 500 pounds per acre | 8.81 | 8.89 | 8.85 | 2.08 | +2.08 | 208 | 14.02 | 14.02 | 14.02 | 6.29 | 3.14 | 52 | 23.72 | 23.75 | 27.73 | 15.39 | 12.24 | 82 | 27.11 | 27.35 | 27.23 | 18.66 | 15.51 | 102 |

eighth day the cultures having ammonium sulfate, and this material plus sodium nitrate equivalent to 50 and 100 pounds per acre, all had less nitrates in the system than a similar portion of untreated soil. Those portions, however, having nitrate of soda equal to 300 and 500 pounds per acre registered a decided increase over the untreated cultures.

On the sixteenth day, however, this stimulative influence seems to have been lost, as a decided decreased accumulation of nitrates was found in all cases, varying from 6 per cent to 48 per cent below the normal nitrification.

When the soils were analyzed for nitrates at the end of the twenty-fourth day this relative depressed accumulation was considerably narrowed and at 50 pounds per acre an actual stimulation of 2 per cent is to be noted. The maximum decrease here is only 18 per cent below the normal. It would seem that from the sixteenth to the twenty-fourth day a marked stimulation to the nitrifying group has occurred, the total nitrates formed being enough to approach the accumulation in the check cultures and to register an enhanced effect.

At the end of the experiment we find a slight increase over the untreated portions in all cases. No decrease in the nitrate accumulation is to be noted in any case which is in confirmation of the previous results.

*Series 15. The influence of sodium nitrate upon the accumulation of nitrates derived from the nitrification of cottonseed meal*

Concerning the effect of sodium nitrate upon the nitrification of cottonseed meal we must come to the same conclusion as was reached in series 20. At the end of 8 days no accumulation of nitrates at all is to be seen.

In sixteen days the applications of sodium nitrate equivalent to 300 and 500 pounds per acre have decreased the accumulation of nitrates 89 and 75 per cent, respectively. On being analyzed for nitrates at the end of the twenty-fourth day the data show that the depressed accumulation is materially lessened, as was the case with ammonium sulfate. At the finish of the experiment the resulting action of sodium nitrate upon nitrification of cottonseed meal is nil.

*Series 16. The influence of sodium nitrate upon the accumulation of nitrates derived from the nitrification of dried blood*

The data concerning the influence of sodium nitrate upon the nitrification of dried blood are given in table 21A. The greatest nitrification of all the materials was at the end of the experiment. The increase in nitrate accumulation from the twenty-fourth to the thirty-second day was small indeed.

An objection to the figures tabulated above can be raised on the grounds that nitrates as well as nitrites are reduced by this reduction method. However, this factor is shown to be insignificant under another experiment.

TABLE 21A

*The influence of sodium nitrate upon the nitrification of dried blood at various intervals*

| LAB. NO. | SPECIAL TREATMENT | 8 DAYS NO₃ accumulation | | | MINUS NO TREATMENT | MINUS $NaNO_3$ ADDED | PER CENT RELATION TO CHECK | 16 DAYS NO₃ accumulation | | | MINUS NO TREATMENT | MINUS $NaNO_3$ ADDED | PER CENT RELATION TO CHECK | 24 DAYS NO₃ accumulation | | | MINUS NO TREATMENT | MINUS $NaNO_3$ ADDED | PER CENT RELATION TO CHECK | 32 DAYS NO₃ accumulation | | | MINUS NO TREATMENT | MINUS $NaNO_3$ ADDED | PER CENT RELATION TO CHECK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mgm. N | Mgm. N | Average Mgm. N | | | | Mgm. N | Mgm. N | Average Mgm. N | | | | Mgm. N | Mgm. N | Average Mgm. N | | | | Mgm. N | Mgm. N | Average Mgm. N | | | |
| 1–2 | Nothing | 6.67 | 6.87 | 6.77 | | | | 7.92 | 7.56 | 7.73 | | | | 8.38 | 8.30 | 8.34 | | | | 8.59 | 8.55 | 8.57 | | | |
| 3–4 | 173 mgm. D. B. | 6.31 | 6.55 | 6.43 | −0.34 | | 100 | 12.93 | 12.93 | 12.93 | 5.20 | | 100 | 23.97 | 24.03 | 24.00 | 15.65 | | 100 | 25.38 | 25.25 | 25.31 | 16.74 | | 100 |
| 5–6 | 173 mgm. D. B. + $NaNO_3$ = 50 pounds per acre | 6.82 | 7.09 | 6.95 | 0.28 | −0.13 | 126 | 13.55 | 13.51 | 13.53 | 5.80 | 5.39 | 102 | 24.23 | 24.17 | 24.20 | 15.95 | 15.44 | 99 | 25.22 | 25.16 | 25.19 | 16.62 | 16.21 | 97 |
| 7–8 | 173 mgm. D. B. + $NaNO_3$ = 100 pounds per acre | 7.15 | 7.21 | 7.18 | 0.41 | −0.42 | 82 | 13.50 | 13.57 | 13.53 | 5.80 | 4.96 | 97 | 24.27 | 24.42 | 24.34 | 16.00 | 15.16 | 97 | 25.78 | 25.82 | 25.80 | 17.23 | 16.29 | 97 |
| 9–10 | 173 mgm. D. B. + $NaNO_3$ = 300 pounds per acre | 8.64 | 8.69 | 8.66 | 1.87 | −0.12 | 126 | 15.00 | 14.78 | 14.92 | 7.19 | 5.20 | 100 | 25.53 | 25.22 | 24.37 | 16.03 | 15.04 | 96 | 27.78 | 27.98 | 27.88 | 19.31 | 16.32 | 97 |
| 11–12 | 173 mgm. D. B. + $NaNO_3$ = 500 pounds per acre | 10.47 | 9.71 | 10.19 | 3.42 | −0.27 | 120 | 15.40 | 15.27 | 15.33 | 7.60 | 3.45 | 66 | 26.00 | 26.14 | 26.07 | 18.73 | 15.58 | 99 | | | | | | |

In attempting to explain the decreased nitrate accumulation due to the presence of sodium nitrate we must again consider the consumption theory as previously explained. Nitrates, as well as ammonia, are readily converted into insoluble forms. Due to the addition of sodium nitrate as well as to nitrification, a marked increase takes place in the numbers of the microflora of the soil. These organisms necessarily need nitrogen for their life process and as nitrates, and even the ammonia from the nitrifying substances are present in excess, they use it for their own life processes. Fred and Graul (38) have given us a neat piece of experimentation on this point, as one will see by consulting the data on page 333 of their article.

We can also tell to a considerable degree just how far this consumption phenomenon is being carried out and when the toxicity factor enters into these experiments, if we titrate the ammonia, not converted into nitrate, which is driven off from the extracted nitrate solution in the carrying out of this reduction method. Although the figures thus obtained cannot be quantitative because of absorption of this ammonia by the soil, it is nevertheless extremely indicative of the point when excess nitrates seem to discourage the nitrifying organisms from converting ammonia into nitrate.

From an examination of the data recorded in table 22 there are to be seen marked differences at the points which sodium nitrate inhibits the nitrifiability of ammonium sulfate, dried blood or cottonseed meal. Toxicity commences to manifest itself in the Carrington loam at a concentration of about 1500 pounds per acre, where dried blood and cottonseed meal are the nitrifiable materials. In the Norfolk sandy loam the depressed action of sodium nitrate upon the nitrifiers is present at smaller concentrations, viz., 500 pounds per acre. When cottonseed meal, however, is the nitrifiable material no toxicity occurs until a concentration of 5000 pounds per acre is present. The toxicity of sodium nitrate to the nitrification of ammonium sulfate was not studied in this connection. Its toxicity to the mineralization of dried blood is evident at a concentration of 2500 pounds per acre and to that of cottonseed meal at 2500 pounds per acre. In the Sierra sandy loam no toxic action is noticed to affect the nitrification of cottonseed meal until a concentration of 5000 pounds per acre is reached. It is here just one-half as great as it is at double this concentration. Noticeable toxicity to the mineralization of dried blood starts quite early, viz., at a concentration of 1200 pounds per acre. Increasing the amount increases the toxic effect. No discouraging action to the nitrifying organisms is present in the Wooster silt loam until a concentration of over 500 pounds per acre of sodium nitrate is reached, with ammonium sulfate and dried blood as the source of nitrogenous material. The maximum toxicity in the Wooster silt loam in so far as the nitrification of dried blood and cottonseed meal is concerned, occurs at a concentration of 5000 to 10,000 pounds per acre.

Of course, in using the reduction method nitrites are reduced, if present, as well as nitrates and the ammonium formed is necessarily the sum of the

TABLE 21B

*The influence of sodium nitrate upon the nitrification of cottonseed meal at various intervals*

| LAB. NO | SPECIAL TREATMENT | 8 DAYS NO$_3$ accumulation Mgm. N | 8 DAYS NO$_3$ accumulation Mgm. N | 8 DAYS NO$_3$ accumulation Average Mgm. N | MINUS NO TREATMENT | MINUS NaNO$_3$ ADDED | PER CENT RELATION TO CHECK | 16 DAYS NO$_3$ accumulation Mgm. N | 16 DAYS NO$_3$ accumulation Mgm. N | 16 DAYS NO$_3$ accumulation Average Mgm. N | MINUS NO TREATMENT | MINUS NaNO$_3$ ADDED | PER CENT RELATION TO CHECK | 24 DAYS NO$_3$ accumulation Mgm. N | 24 DAYS NO$_3$ accumulation Mgm. N | 24 DAYS NO$_3$ accumulation Average Mgm. N | MINUS NO TREATMENT | MINUS NaNO$_3$ ADDED | PER CENT RELATION TO CHECK | 32 DAYS NO$_3$ accumulation Mgm. N | 32 DAYS NO$_3$ accumulation Mgm. N | 32 DAYS NO$_3$ accumulation Average Mgm. N | MINUS NO TREATMENT | MINUS NaNO$_3$ ADDED | PER CENT RELATION TO CHECK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1–2 | Nothing | 6.67 | 6.87 | 6.77 | | | | 7.92 | 7.56 | 7.73 | | | | 8.38 | 8.30 | 8.34 | | | | 8.59 | 8.55 | 8.57 | | | |
| 3–4 | 300 mgm. C. S. M. | 6.84 | 7.05 | 6.94 | 0.27 | | 100 | 14.15 | 14.31 | 14.23 | 6.50 | | 100 | 17.55 | 17.26 | 17.40 | 9.06 | | 100 | 18.07 | 18.47 | 18.27 | 9.70 | | 100 |
| 5–6 | 300 mgm. C. S. M. + NaNO$_3$ = 50 pounds per acre | 7.03 | 6.76 | 6.89 | 0.11 | −0.30 | 0 | 14.50 | 14.16 | 14.33 | 6.60 | 5.18 | 79 | 16.99 | 17.95 | 17.51 | 9.17 | 8.76 | 97 | 18.67 | 18.71 | 18.69 | 10.12 | 9.71 | 100 |
| 7–8 | 300 mgm. C. S. M. + NaNO$_3$ = 100 pouds per acre | 7.50 | 6.87 | 7.18 | 0.41 | −0.43 | 0 | 15.28 | 15.28 | 15.28 | 7.55 | 6.72 | 103 | 17.63 | 17.74 | 17.68 | 9.34 | 8.50 | 94 | 18.71 | 18.57 | 18.64 | 10.07 | 9.28 | 896 |
| 9–10 | 300 mgm. C. S. M. + NaNO$_3$ = 300 pounds per acre | 8.44 | 8.44 | 8.44 | 1.67 | −0.32 | 0 | 15.49 | 15.67 | 15.58 | 7.85 | 5.86 | 89 | 19.00 | 18.87 | 18.93 | 10.59 | 8.60 | 95 | 20.23 | 20.18 | 20.45 | 11.88 | 9.89 | 102 |
| 11–12 | 300 mgm. C. M. S. + NaNO$_3$ = 500 pounds per acre | 9.71 | 9.71 | 9.71 | 2.94 | −0.21 | 0 | 15.95 | 15.40 | 15.67 | 7.94 | 4.79 | 75 | 20.18 | 20.32 | 20.50 | 12.16 | 9.01 | 99 | | | | | | |

two. Kelley (83) considers that a considerable amount of nitrites is formed when amounts of organic matter are present in excess of what he proposes as a standard, i.e., 10 mgm. of nitrogen per 100 gm. of soil. As approximately twice that figure was used in these experiments it is evident, if his conclusions are tenable, that large amounts of nitrites have been formed and are recorded as nitrates.

At the same time while we consider this question of nitrite formation it is not out of place to note, if possible, whether sodium nitrate will discourage the action of *Nitrobacter* and allow the production of considerable quantities of nitrites. Kelley has noted that certain alkali salts seem to cause such a phenomenon. It is of importance to know if considerable amounts of nitrites are formed because of their extreme toxicity to plants.

TABLE 22

*Nitrogen as ammonia not nitrified in the presence of sodium nitrate*

| $NaNO_3$ PER ACRE | CARRINGTON LOAM | | | NORFOLK SANDY LOAM | | | PENN CLAY LOAM | | | SIERRA SANDY LOAM | | | WOOSTER SILT LOAM | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | From $(NH_4)_2SO_4$ | From dried blood | From cotton seed | From $(NH_4)_2SO_4$ | From dried blood | From cotton seed | From $(NH_4)_2SO_4$ | From dried blood | From cotton seed | From $(NH_4)_2SO_4$ | From dried blood | From cotton seed | From $(NH_4)_2SO_4$ | From dried blood | From cotton seed |
| *lbs.* | *mgm.* | *mgm.* | *mgm.* | *mgm.* | | *mgm.* | | *mgm.* | *mgm.* | *mgm.* | *mgm.* | *mgm.* | *mgm.* | *mgm.* | *mgm.* |
| None | 0.90 | 0.90 | 0.90 | 0.54 | Not determined | 0.54 | Not determined | 0.31 | 0.31 | 0.26 | 0.60 | 0.26 | 0.56 | 0.56 | 0.56 |
| 50 | 1.17 | 0.76 | 0.76 | 4.15 | | 0.54 | | 0.31 | 0.82 | 9.35 | 0.98 | 0.60 | 0.56 | 9.92 | 2.37 |
| 100 | 1.17 | 0.76 | 0.76 | 4.69 | | 0.54 | | 0.31 | 0.82 | 10.63 | 1.35 | 0.60 | 0.56 | 9.92 | 3.73 |
| 300 | 1.17 | 0.76 | 0.76 | 4.94 | | 0.54 | | 0.31 | 0.82 | 9.30 | 1.50 | 0.60 | 0.56 | 9.92 | 5.40 |
| 500 | 1.17 | 0.76 | 0.76 | 5.10 | | 0.54 | | 0.31 | 0.82 | 11.42 | 2.54 | 0.60 | 0.56 | 9.54 | 6.19 |
| 700 | 1.17 | 0.76 | 0.76 | 6.70 | | 0.54 | | 0.31 | 0.82 | 11.47 | 1.35 | 0.60 | 1.06 | 10.49 | 6.63 |
| 900 | 1.17 | 0.76 | 0.76 | 7.32 | | 0.54 | | 0.31 | 2.82 | 11.47 | 2.12 | 0.60 | 2.18 | 11.32 | 6.63 |
| 1,200 | 2.78 | 0.76 | 0.76 | 9.39 | | 0.54 | | 0.31 | 2.02 | | 3.91 | 0.60 | 5.30 | 11.30 | 7.35 |
| 1,500 | 2.78 | 0.76 | 0.76 | | | 0.54 | | 0.31 | 2.02 | 11.77 | 3.88 | 0.60 | 6.20 | 12.22 | 6.82 |
| 2,500 | 3.84 | 4.92 | 0.76 | 11.22 | | 0.54 | | 4.29 | 4.27 | 12.94 | 4.77 | 0.60 | 8.50 | 13.47 | 16.23 |
| 5,000 | 7.68 | 11.76 | 5.43 | 11.50 | | 2.37 | | 9.60 | 8.46 | 14.76 | 10.38 | 3.55 | 17.74 | 16.93 | 16.25 |
| 10,000 | 16.69 | 16.87 | 11.76 | 16.32 | | 4.74 | | 13.27 | 10.79 | 17.76 | 13.95 | 6.65 | 19.48 | 18.19 | 16.23 |

*Series 17. The influence of $NaNO_3$ upon the accumulation of nitrites formed in the nitrification of various manures*

In order to test this out, therefore, a new series of experiments were set up, the extractions from the Carrington loam being used, in which the effect of sodium nitrate had been tested upon the nitrification of cottonseed meal, dried blood and ammonium sulfate (tables 18, 19 and 20). Nitrites were determined colorimetrically by the Greiss method (106). From an analysis of the data in table 23 it will be readily seen, considering the first point raised, that the amount of nitrites formed in any case is not one part per million. This amount would be equivalent to about one drop of N/50 acid, as used in the

reduction method. The figures, then, represent actual quantities of nitrates and not the sum of the two.

To take up next the action of sodium nitrate upon the accumulation of nitrites we find that while there is a general tendency for this radical to increase in amount, it does not reach a concentration of one part per million in any soil until a concentration of from 5,000 to 10,000 pounds per acre is present. At a concentration of 10,000 pounds per acre we find a high amount of nitrite formed in the nitrification of dried blood; on the other hand, only 3.50 and 2.36 parts per million result from the action of sodium nitrate upon the nitrification of the other two materials.

It is clear then that *Nitrobacter* must be influenced in a manner similar to *Nitrococus*, or else we would get an accumulation of nitrites rather than nitrates.

TABLE 23

*The influence of sodium nitrate on the nitrites formed in the nitrification of various manure*

| SOIL PORTION | POUNDS PER ACRE $NaNO_3$ | CARRINGTON LOAM | CARRINGTON LOAM | CARRINGTON LOAM |
|---|---|---|---|---|
| | | $(NH_4)_2SO_4$ | Dried blood | Cottonseed meal |
| | | *p.p.m. as mgm. N* | *p.p.m. as mgm. N* | *p.p.m. as mgm. N* |
| Check | Untreated | 0.2143 | 0.2143 | 0.2143 |
| 1–2 | No nitrate + Manure | 0.2143 | 0.7390 | 0.6420 |
| 3–4 | 50 | 0.2405 | 0.7620 | 0.6630 |
| 5–6 | 100 | 0.2143 | 0.9135 | 0.6940 |
| 7–8 | 300 | 0.1748 | 0.9203 | 0.5570 |
| 9–10 | 500 | 0.2185 | 0.9203 | 0.6995 |
| 11–12 | 900 | 0.2710 | 0.8410 | 0.6630 |
| 13–14 | 1,500 | 0.2143 | 0.9500 | 0.6765 |
| 15–16 | 2,500 | 0.2185 | 1.0370 | 0.7325 |
| 17–18 | 5,000 | 0.5865 | 2.3000 | 0.6200 |
| 19–20 | 1,000 | 3.5200 | 10.710 | 2.3600 |

The larger accumulation of nitrites at a concentration of 10,000 pounds per acre, would lend support to the opposite view, however. Kelley finds that nitrites are toxic to *Nitrobacter* in large quantities, i.e., 40 mgm. per 100 gm. of soil. Smaller amounts, however, do not affect this condition. As the concentration of sodium nitrate rarely reaches such a figure we need have no fear of nitrites forming in such quantities as to inhibit either plant growth or biological activities.

To summarize the influence of sodium nitrate upon the nitrifying process in the soils it would seem as if the earlier views of Lipman and Brown (109) Crowther (23) and Miyake (127) were substantiated, namely, that sodium nitrate does enhance the nitrification process to a greater or less extent. This stimulating effect may not necessarily be superficially observed, but on the other hand, may cause secondary stimulations to set in, whereby large increases

in the numbers of other soil organisms are brought about, these organisms using the nitrate as well as the nitrifiable material as a source of energy and food. Thus the stimulative effect may be entirely hidden and a decreased accumulation of nitrates be noted instead.

In large quantities, as one would naturally suspect, the presence of nitrates discourages the action of the nitrifying group. In the nitrifying group we have only two known sepcies of bacteria. Necessarily then, we can have no survival of organisms from the action of high salt concentrations, the entire group being eliminated at once.

Deherain (25) says that whereas sodium nitrate may at first depress the activity of the nitrifying group, after some time the organisms readjust themselves to this high concentration and become active. In an experiment carried out by him he added 6 centigrams of sodium nitrate to 100 gm. of fresh soil and noted the nitrates formed at the end of 30 days. He found none; however, shortly after this the soil commenced to nitrify vigorously.

It is also of interest to cite the work of Russel (156) at this point, on the nature and amount of the fluctuation of nitrates in arable soils. This investigator reports that the maximum amount of nitrate accumulation in sand, loams and clays during the year is 6 parts per million in the sands, 14 parts in clays and 23 parts in loams. The action may no doubt also be partially explained by the above phenomenon, viz., the increased cell division, with subsequent transformation of the soluble material.

The fact that nitrates are assimilated again raises the question as to whether or not this does not seriously affect the availability of nitrogenous manures. Being bound up in the body tissue of the microörganisms they must be mineralized during the growing season to be especially beneficial to the crop. If they are not readily simplified a serious problem is at hand, over which the farmer has very little control. The availability of bacterial nitrogen will be studied later on in the text.

In Colorado there are many soils seriously affected by high accumulations of nitrates. Sackett's (147) work would lead one to believe that these nitrate accumulations were of bacterial origin. As the transformation and accumulation of nitrates would have the same scientific interest as the application of sodium nitrate would have upon soils not affected with niter trouble, it was thought that a comparison of the activities of a Colorado "niter spot" soil with the action of sodium nitrate in the above soils would be interesting.

Through Professor Sackett's kindness the author was able to secure such a soil and the data concerning its biological activity are given in series 18.

*Series 18. The ammonifying, nitrifying and nitrogen-fixing power of a Colorado niter-spot soil*

In collecting this soil, samples were taken under sterile conditions and shipped to the New Jersey Station by express. On arrival they were spread out to dry on a piece of sterile wrapping paper. The soil was a sandy loam

very low in organic matter. All samples were taken from the same field. Sample 1 was taken in the niter spot itself; sample 2 where the effects of the niter spot were just beginning, and sample 3 where no effects were to be noted. The soils were analyzed for total nitrates and chlorides, with the results shown in table 24.

The various biological tests carried out on these samples were ammonification, nitrification and nitrogen fixation. Fixation was carried out in solution because of the lack of soil.

TABLE 24

*Nitrates and chlorides in Colorado soil samples*

| | Milligram per 100 gm. of soil | |
|---|---|---|
| | $NO_3$ as N | Cl |
| Sample 1 | 4.78 | 144.87 |
| Sample 2 | 0.86 | 2.91 |
| Sample 3 | 0.72 | 1.94 |

TABLE 25

*Ammonifying power of the niter spot samples*

| Soil | Ammonia nitrogen accumulation | | Average | Per cent relation to sample 3 |
|---|---|---|---|---|
| *Dried blood* | | | | |
| | *mgm.* | *mgm.* | *mgm.* | |
| Sample 1 | 0.93 | 0.93 | 0.93 | 0 |
| Sample 2 | 18.53 | 19.45 | 18.99 | 70 |
| Sample 3 | 26.52 | 26.95 | 26.73 | 100 |
| *Cottonseed meal* | | | | |
| Sample 1 | 10.79 | 10.50 | 11.14 | 48 |
| Sample 2 | 18.15 | 16.37 | 17.26 | 74 |
| Sample 3 | 23.00 | 23.00 | 23.00 | 100 |

The ammonifying power of the soil samples was first studied, dried blood and cottonseed meal being used as the source of organic matter. The data are given in table 25.

It will be seen that, giving sample 3 a value of 100, there is a gradual decrease in the ammonifying power of the samples as the niter spot is approached. Sample 2 has an ammonifying power of 72, on an average, for both sources of organic matter. Sample 1 was not able to ammonify dried blood, although it could simplify cottonseed meal to a large extent. This is in keeping with the increased toxic effect of sodium nitrate where cottonseed meal was used as the source of organic matter in ammonification work. In this case, how-

ever, the decreased activity cannot be due to increases in nitrates, as can be seen from table 23.

The next experiment, recorded in table 25, was carried out to test the nitrifying power of the three samples. By consulting the table we find marked differences in the ability of these three soils to nitrify the three sources of organic matter.

Considering first ammonium sulfate, we find sample 2 nitrifying this material to a very small extent. In fact the nitrification of this substance in sample 2 and that in sample 3 are nearly alike. However, with dried blood a somewhat greater nitrification took place than with ammonium sulfate in samples 2

TABLE 26

*The nitrifying power of the niter spot soils*

| SAMPLE NUMBER | $NH_4SO_4$ Nitrate accumulation Mgm. N | $NH_4SO_4$ Nitrate accumulation Mgm. N | $NH_4SO_4$ Nitrate accumulation Average mgm. N | PER CENT RELATION TO CHECK | DRIED BLOOD Nitrate accumulation Mgm. N | DRIED BLOOD Nitrate accumulation Mgm. N | DRIED BLOOD Nitrate accumulation Average mgm. N | PER CENT RELATION TO CHECK | COTTONSEED MEAL Nitrate accumulation Mgm. N | COTTONSEED MEAL Nitrate accumulation Mgm. N | COTTONSEED MEAL Nitrate accumulation Average mgm. N | PER CENT RELATION TO CHECK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.69 | 1.79 | 1.74 | 16 | 1.65 | 1.75 | 1.70 | 18 | 1.57 | 1.57 | 1.57 | 27 |
| 2 | 1.68 | 1.68 | 1.68 | 16 | 4.59 | 4.59 | 4.72 | 41 | 3.93 | 4.22 | 4.07 | 71 |
| 3 | 10.31 | 10.33 | 10.32 | 100 | 8.65 | 9.51 | 9.08 | 100 | 5.90 | 5.55 | 5.72 | 100 |

TABLE 27

*Nitrogen-fixing powers of the niter spot samples*

| | NITROGEN FIXED | | AVERAGE | PER CENT RELATION TO SAMPLE 3 |
|---|---|---|---|---|
| | *mgm.* | *mgm.* | *mgm.* | |
| Sample 1 | 2.47 | 2.95 | 2.71 | 19 |
| Sample 2 | 13.47 | 11.11 | 13.29 | 94 |
| Sample 3 | 14.21 | 13.97 | 14.07 | 100 |

and 3. Likewise cottonseed meal gave a relative stimulation considerably greater than the other two sources of nitrifiable material. Taking a comparison between the action of sodium nitrate in large quantities upon the nitrification of these nitrifiable materials, we find a close parallelism between the phenomenon there registered and here.

Repeating the work on the nitrogen-fixing powers of these three samples we find from the data in table 27 that there is also a decreased nitrogen fixation as the samples approach the niter spot.

## PART IV

### *Series 19. The influence of sodium nitrate upon nitrogen fixation*

The various biological activities already considered deal with the transformation of soil nitrogen. Starting with the complex protein molecule, we have seen how sodium nitrate acts first upon the ammonifying group and second, upon the nitrifying group. Whatever the complexity of these processes, whatever the inter-relation or inter-dependence of the several bacterial factors, they can add nothing to the store of soil nitrogen. Whatever the rate of ammonification, the soil nitrogen cannot thereby increase in amount. Fortunately, there are compensating factors. Just as the nitrogen atoms may be torn apart from those of other elements, so may the latter be made to combine with other elements in the formation of new nitrogen compounds. These compensating factors are the various species of nitrogen-fixing bacteria.

The influence of nitrates as a factor in affecting the activities of the nitrogen-fixing organisms has been studied by a host of investigators, among whom may be cited Heinze (69), Headden (68), Lipman (105), Strank (182), Stocklassa (179) and Sackett (159). So numerous are the experiments upon this phase of the soil nitrogen problem, it is hardly necessary to go into it in any detail, other than to corroborate the findings of previous investigators.

In order to throw some added light upon the question of nitrogen-fixation and soluble nitrogen, two experiments were instituted, the one conducted in solution and the other in the Norfolk sandy loam.

The effect of sodium nitrate upon nitrogen-fixation was first studied in solution.

Fifty cubic centimeters of Sohm's soil mannite broth was placed in 500-cc. Florence flasks. Sodium nitrate was then added in quantities as shown in table 28. The flasks were then inoculated with a vigorous culture of nitrogen-fixing organisms.[2] After inoculation, the flasks were incubated for 21 days at 20°C. At the end of this time the total nitrogen in the system was determined, the nitrates being reduced by means of salicylic acid and zinc dust. The total nitrogen at the beginning of the experiment, as well as the nitrogen in the nitrates added, also was determined.

It will be seen from an observation of the data in table 28, that small amounts of sodium nitrate slightly increased the amount of nitrogen fixed. As the nitrogen increases, however, the fixation rapidly diminishes, depending upon the amount of nitrates in the system. These data seem to be in line with the earlier solution studies of Lipman, Heinze and Stocklassa, i.e., that small amounts of nitrates stimulate the activity of the *Azotobacter*, whereas when larger quantities are present this action is discouraged, the organisms living upon the nitrates.

No work has come to the writer's attention in which this phenomenon has been observed under actual soil conditions. In order to study the process

[2] The culture was obtained through the kindness of Dr. H. C. Lint, of the Alphano Humus Company, New York City.

in soils, a second experiment was started, the Norfolk sandy loam being used.

To 50 gm. of Norfolk sandy loam in tumblers, were added 2 gm. of dextrose and 2 gm. of the same inoculating material. The whole was then thoroughly mixed together and sodium nitrate added, as is shown in table 28. Water was adjusted to 50 per cent of the water-holding capacity and the soils were incubated for 21 days as before. At the end of this time they were thoroughly air-dried and analyzed for total nitrogen, the nitrates being reduced with salicylic acid and zinc dust.

It will be seen from an examination of table 28 that a similar set of affairs is present in this series as was noted in the solution study, namely, a decrease in the amount of nitrogen fixed varying with the size of the application. At a concentration of 1500 pounds per acre in this experiment, the nitrogen-fixing organisms ceased to fix any more atmospheric nitrogen.

TABLE 28

*The effect of sodium nitrate upon the fixation of atmospheric nitrogen*

| LAB. NO. | NITROGEN FIXATION IN SOLUTION | | | | | | PER CENT RELATION TO CHECK | NITROGEN FIXATION IN NORFOLK SANDY LOAM | | | | | | PER CENT RELATION TO CHECK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $NaNO_3$ added | Total nitrogen in solution | | | Minus no treatment | Minus $NaNO_3$ added | | $NaNO_3$ pounds per acre | Nitrogen in 50 grams soil | | | Minus no treatment | Minus $NaNO_3$ added | |
| | | Mgm. N | Mgm. N | Average mgm. N | | | | | Mgm. N | Mgm. N | Average mgm. N | | | |
| | *mgm.* | | | | *mgm.* | *mgm.* | | | | | | *mgm.* | *mgm.* | |
| 1–2 | Check | 38.14 | 38.14 | 38.14 | | | | Check | 41.87 | 42.97 | 42.42 | | | |
| 3–4 | None | 57.40 | 56.58 | 56.99 | 18.85 | 18.85 | 100 | None | 56.62 | 55.55 | 54.08 | 9.66 | 9.66 | 100 |
| 5–6 | 5 | 57.83 | 57.75 | 57.99 | 19.83 | 19.22 | 102 | 100 | 52.62 | 54.20 | 53.41 | 10.93 | 9.98 | 103 |
| 7–8 | 10 | 59.49 | 59.27 | 59.38 | 21.24 | 19.76 | 105 | 200 | 53.50 | 53.50 | 53.50 | 11.08 | 8.56 | 88 |
| 9–10 | 25 | 62.19 | 61.32 | 61.75 | 23.61 | 19.98 | 106 | 600 | 50.25 | 51.60 | 50.92 | 8.50 | 4.12 | 42 |
| 11–12 | 50 | 63.75 | 63.20 | 63.47 | 25.33 | 17.58 | 90 | 1,000 | 53.35 | 51.50 | 52.42 | 10.00 | 3.17 | 32 |
| 13–14 | 100 | 67.42 | 68.34 | 67.88 | 29.74 | 14.14 | 75 | 1,500 | 50.65 | 50.65 | 50.65 | 8.23 | −1.00 | 0 |
| 15–16 | 250 | | 87.25 | 87.25 | 49.11 | 10.37 | 55 | | | | | | | |

The question is asked whether this discouraged activity is due to a concentration of the sodium salt or to some other cause. We know that sodium nitrate increases bacterial activity to a great extent. Perhaps the presence of this salt increased the bacterial numbers to such an extent that the increased host of microbes used up all of the available energy that the *Azotobacter* require to fix elementary nitrogen. Or again, the increased numbers may have made it difficult for *Azotobacter* to work very handily.

Bearing upon this point Lipman (105) has data showing that *Azotobacter Vinelandii* is seriously inhibited in its own nitrogen-fixing power by the presence of ammonia and nitrate salts.

It would seem, considering the work of the earlier investigators as well as the experiments tabulated here, that the nitrogen-fixing power in the soil is discouraged by applications of sodium nitrate, although in solution a slight

stimulating action is to be seen. This decreased fixation is to be explained on several grounds, among which are concentration, antagonism of other organisms, the using up of the energy supply by other organisms, and the discouragement of fixation by the use of sodium nitrate as a food by *Azotobacter*.

## PART V

### *Series 20. The transformation of nitrates by soil microörganisms*

*Experiment 1.* It has been shown in the previous pages that soil microorganisms are able to use soluble nitrogen in their life processes. Moreover, it has developed that the amount and efficiency with which they assimilate ammonia or nitrates depends to a very large extent upon the kind and amount of energy-providing material. All other things being equal, the assimilation is in direct proportion to the supply of energy.

Necessarily, soils must vary in the amounts of available energy which they contain. The great mass of organic matter left in the roots and that added annually to the soil in the form of green and farm manures contains a low percentage of nitrogen and a high proportion of energy-providing materials. This excess energy must affect the activity of the soil organisms, and hand and hand with this the soluble plant-food in soils.

Again experiments carried out in solution have indicated that the form in which the various nitrates are supplied has much to do with their assimilation. Kossowitz (92) and de Grazia (53) have published data to the effect that calcium nitrate is more resistant to transformation than sodium nitrate.

In order to throw some light upon this point with regard to the same action in soils a new series of experiments were set up to test the relative assimilability of sodium nitrate, potassium nitrate, and calcium nitrate in three types of soil; also the relative assimilability of these nitrates when supplied to a soil with large amounts of energy material.

The experiments were carried out as follows:

One-hundred-gram portions of three types of soil, the Carrington loam, Norfolk sandy loam, and the Penn clay loam were placed in tumblers and the three nitrate-bearing salts added to them in amounts equal to 200 mgm. of the salt. Water was then supplied to 50 per cent of the water-holding capacity. The tumblers were covered with glass plates and incubated at 20°C. for 21 days. Where organic matter was supplied this was added to the soil by means of the mixer previously cited. At the beginning and at the end of the experiment the soils were extracted with water until they showed the presence of no nitrates by the diphenylamine reaction as outlined by Withers and Ray (224).

It is assumed that the soluble nitrogen not in the form of ammonia or nitrates has been attacked by microörganisms in such a manner as to make them of no use for plant growth.

The data recording the transformation of the three nitrate-bearing salts in the three above-mentioned soils are given in table 29. In this table columns 1 and 2 express the ammonia present in the soils at the beginning and at the

end of the experiment, column 4 the amount of nitrate applied in milligrams of nitrogen, column 3 the total nitrates in the soil including the soil nitrates, column 5 the total nitrates at the end of the experiment, column 6 the total applied nitrates at the end of the experiment, column 7 the milligrams of total applied nitrates transformed and column 8 the per cent of applied nitrogen transformed.

From an examination of the table it is to be seen that the total amount of nitrates assimilated varies from 15 to 30 per cent with a general average of about 22 per cent in all soils and with all sources of nitrates. In the Norfolk sandy loam 23.56 per cent of the nitrogen of sodium nitrate was transformed, in the Penn loam clay 20 per cent and in the Carrington loam 24.27

TABLE 29

*Transformation of $Ca(NO_3)_2$, $KNO_3$, and $NaNO_3$ in various soils*

| LAB. NO. | SOIL AND TREATMENT | $NH_3$ AT BEGINNING MGM. N | $NH_3$ AT END MGM. N | TOTAL $NO_3$ AT BEGINNING MGM. N | N AS $NO_3$ APPLIED MGM. N | TOTAL $NO_3$ AT END MGM. N | TOTAL APPLIED $NO_3$ AT END MGM. N | APPLIED NITROGEN TRANSFORMED MGM. N | PER CENT OF APPLIED N TRANSFORMED |
|---|---|---|---|---|---|---|---|---|---|
| 1–2 | N. S. L. no treatment | 0.42 | 0.45 | 1.67 | | 3.01 | | | |
| 3–4 | N. S. L. + $NaNO_3$ | 0.42 | 0.48 | 30.02 | 28.35 | 24.68 | 21.67 | 6.68 | 23.56 |
| 5–6 | N. S. L. + $KNO_3$ | 0.42 | 0.47 | 39.17 | 37.50 | 31.79 | 28.78 | 8.72 | 23.26 |
| 7–8 | N. S. L. + $Ca(NO_3)_2$ | 0.42 | 0.45 | 34.42 | 32.75 | 30.67 | 27.66 | 5.09 | 15.52 |
| 9–10 | P. C. L. no treatment | 0.28 | 0.28 | 2.25 | | 7.89 | | | |
| 11–12 | P. C. L. + $NaNO_3$ | 0.28 | 0.29 | 30.60 | 28.35 | 30.57 | 22.68 | 5.67 | 20.00 |
| 13–14 | P. C. L. + $KNO_3$ | 0.28 | 0.28 | 39.75 | 37.50 | 37.08 | 29.19 | 7.31 | 19.45 |
| 15–16 | P. C. L. + $Ca(NO_3)_2$ | 0.28 | 0.28 | 35.00 | 32.75 | 31.19 | 23.30 | 9.45 | 28.85 |
| 17–18 | C. L. no treatment | 0.27 | 0.27 | 3.37 | | 6.38 | | | |
| 19–20 | C. L. + $NaNO_3$ | 0.26 | 0.28 | 31.72 | 28.35 | 28.84 | 21.47 | 6.88 | 24.27 |
| 21–22 | C. L. + $KNO_3$ | 0.28 | 0.27 | 41.87 | 37.50 | 36.00 | 29.63 | 7.87 | 20.99 |
| 23–24 | C. L. + $Ca(NO_3)_2$ | 0.28 | 0.28 | 36.12 | 32.75 | 31.43 | 25.06 | 7.69 | 23.45 |

per cent. The amount of nitrogen as calcium nitrate assimilated seems to be at a minimum in the Norfolk sandy loam and at a maximum in the Penn clay loam. Potassium nitrate was effectively transformed in the Carrington loam and Penn clay loam soils.

Comparing the assimilation of calcium nitrate with that of the other two salts it can not be said, as a generalization, that it is more resistant to transformation than they are. The relatively large percentage of assimilation of the three salts is quite remarkable and may well enter into the availability question as a partial explanation of the lack of recovery of the total nitrogen supplied in mineral fertilizers. In these three soils the different amounts of organic matter no doubt supplied the energy for the above phenomenon. We can, however, cause a similar phenomenon to take place by using standard soils and supplying organic matter in various forms.

*Experiment 2.* In this experiment the effect of barley straw was studied on the assimilation of these three salts. It will be seen by consulting table 30 which is constructed on the same order as table 29 that very much larger amounts of soluble nitrates are taken out of solution. The greatest amount of nitrate assimilated in this experiment was in the form of potassium nitrate. As was the case with this soil in the previous experiment, calcium nitrate was the least assimilated.

The phenomenon of assimilation has been predominant in all of the previous series of investigations. Once in the proptoplasm of the microörganisms it must again become mineralized before it can be used by the plant. It is of great importance to us to know how fast this combined nitrogen will become available again. Beijernick (7) has some data on this point. He found that some 50 per cent of the total nitrogen of *Azotobacter* cells which he supplied was

TABLE 30

*The transformation of nitrates from various sources in a Norfolk sandy loam rich in organic matter*

| SOIL PORTION | SPECIAL TREATMENT | $NH_3$ AT BEGINNING MGM. N | $NH_3$ AT END MGM. N | APPLIED $NO_3$ AT BEGINNING MGM. N | TOTAL $NO_3$ AT BEGINNING MGM. N | TOTAL $NO_3$ AT END MGM. N | SOIL NITRATES TRANSFORMED MGM. N | APPLIED $NO_3$ AT END MGM. N | APPLIED $NO_3$ TRANSFORMED MGM. N | PER CENT APPLIED $NO_3$ TRANSFORMED | PER CENT OF SOIL $NO_3$ TRANSFORMED |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1–2 | No treatment....... | 0.42 | 0.45 | | 1.67 | 3.01 | | | | | |
| 3–4 | 2 per cent Barley straw............. | 0.42 | 0.28 | | 1.67 | 1.09 | 1.92 | | | | 63.78 |
| 5–6 | 2 per cent Barley straw + $NaNO_3$... | 0.42 | 1.65 | 28.35 | 30.02 | 14.22 | | 13.13 | 15.22 | 53.69 | |
| 7–8 | 2 per cent Barley straw + $KNO_3$.... | 0.42 | 1.67 | 37.50 | 39.17 | 14.79 | | 13.70 | 23.80 | 63.48 | |
| 9–10 | 2 per cent Barley straw $Ca(NO_3)_2$.... | 0.42 | 1.69 | 32.75 | 34.42 | 20.00 | | 18.91 | 13.84 | 42.27 | |

nitrified in about seven weeks' time. Biereima (10) also has worked on the question. He found that the condition of the protoplasm was a limiting factor in the process of mineralization. Organisms having a large abundance of spores nitrified very little, whereas those not in this condition were nitrified some 20 to 40 per cent in two months. The writer has also carried out an experiment on this point in which the nitrifiability of some common soil organisms has been studied. The method of obtaining the microörganic substance is as follows:

A sterile portion of Cook's (19) No. 2 medium was inoculated with pure cultures of soil fungi and incubated for 12 days. At the end of this time the microbial matter was killed by sterilization and the dead substance filtered off upon filter paper and washed free from nitrates. The material was then dried at 100°C. and ground with nitrogen-free quartz sand.

A similar process was used to obtain a bulk of *B. mycoides* protoplasm. In this case, however, sterile bouillon was inoculated with this organism and at the end of the incubation period the bacterial mass was removed by means of a Berkefeld filter, washing the substance with distilled water until free from foreign matter. It was then dried and ground with sand. A culture of *Actinomyces penicilloides* was also obtained on the same manner as the fungus material was secured.

Total nitrogen determinations were then made upon the sand plus microörganisms and enough of the material to equal 21 mgm. of nitrogen was used to test its nitrifiability. The Carrington loam was used, as this soil had a powerful nitrifying flora.

For comparative purposes the nitrifiability of cottonseed meal, alfalfa, dried blood and green rye were likewise studied at the same time.

In recording the data given in table 31 the relative values of the materials have been worked out, giving dried blood a value of 100. It is readily seen from a survey of table 31 that there is quite a variation in the nitrifiability of

TABLE 31

*Nitrification of microörganic substance*

| SOURCE OF NITROGEN | $NO_3$ ACCUMULATION | | AVERAGE MGM. N | PER CENT RELATION TO DRIED BLOOD |
|---|---|---|---|---|
| | Mgm. N | Mgm. N | | |
| *Actinomyces penicilloides* | 0.18 | | 0.18 | 0 |
| *Alfalfa meal* | 6.10 | 2.77 | 6.43 | 41.0 |
| *Aspergillus niger* | 6.20 | 6.30 | 6.25 | 41.0 |
| *Bacillus mycoides* | 1.18 | 1.18 | 1.18 | 0.5 |
| *Cottonseed meal* | 9.86 | 9.96 | 9.91 | 65.0 |
| *Cladosporium herbarum* | 4.42 | 4.42 | 4.42 | 28.0 |
| *Dried blood* | 15.23 | 15.39 | 15.31 | 100.0 |
| *Fusarium bullatun* | 15.39 | 9.03 | 12.21 | 79.0 |
| *Mucor spinosus* | 9.93 | 7.24 | 8.58 | 76.0 |
| *Rhizopus tritica* | 10.63 | 8.93 | 9.78 | 65.0 |
| *Rye* | 2.20 | 2.05 | 2.12 | 1.0 |

microbial material, the nitrates formed varying from 0 to 79 per cent of the value of the dried blood.

The organisms most readily nitrified were *Fusarium bullatum* and *Mucor spinosis*. The two organisms were even more nitrifiable than an equivalent quantity of nitrogen as cottonseed meal or alfalfa meal. *Rhizopus tritica* also nitrified as well as cottonseed meal, and superior to rye or alfalfa. In fact, rye did not nitrify at all during the incubation period. *Aspergillus niger*, very rich in spores, was of low nitrifiability; this was likewise true of *Cladosporium herbarium.*

The only bacterium and *Actinomyces* experimented with nitrified but little. Bierima's (10) data on this point, however, give the nitrifiability of *Bacillus agreste* as 18 per cent, *Bacillus radiobacter* 9 per cent and *Bacillus fluorescens* 18 per cent of the total nitrogen supplied, at the end of 2 months.

Taking the whole information on this subject *per se*, it would appear that this nitrogen would probably not become available for crop use until too

late in the season. This would again strengthen our stand that the assimilation of soluble mineral fertilizers has much to do with the ultimate recovery of applied nitrogen.

In the preceding pages an attempt has been made to study the influence of sodium nitrate upon the nitrogen transformation in soils, with a view of obtaining a more perfect understanding of the various factors which go to affect the availability of this manure. Some of the more pertinent points brought out in the investifation have been summarized below. Necessarily all the details cannot be summarized and the reader must consult the text for the finer points of the investigation.

In carrying out the work the author has had the ever helpful advice of Dr. J. G. Lipman, whom he now takes the opportunity to thank most heartily. In addition the author wishes to thank Prof. A. W. Blair, Dr. William S. Myers and the members of the Soil Fertility Research Laboratory of Rutgers College for their kindly interest and suggestions during the course of the investigation.

## SUMMARY

1. It has been shown by a review of the literature upon the availability of nitrogenous manures that a given quantity of nitrogen in the form of nitrates is superior to the same quantity in the form of ammonia and this in turn is of more value than organic forms.

2. Theories for these relative availabilities have been presented and discussed.

3. The reasons why a higher proportion of the applied nitrogen of sodium nitrate is not recovered are also discussed and the probability of these differences being explained on biological grounds is studied in detail.

4. In studying the influence of sodium nitrate upon nitrogen transformation in soils, its effect upon the ammonifying, nitrifying and nitrogen-fixing powers of seven types of soil has been taken up.

5. It has been shown that applications of sodium nitrate markedly increase the simplification of protein material applied to soils.

6. There is some difference to be noted, however, with regard to the source of organic matter.

7. Cottonseed meal is ammonified to a much larger extent in the presence of sodium nitrate than is dried blood.

8. The lesser effect of the action of sodium nitrate upon the ammonification of dried blood is only apparent, and not real.

9. This is due to the effect of this fertilizer in increasing bacterial activity, these increased numbers assimilating the end point.

10. A method for studying this assimilating phenomenon has been outlined and successfully used.

11. Acid phosphate increases the ammonification of dried blood nitrogen, but sodium nitrate added as a limiting factor does not enhance the decay of this material.

12. Potash in the form of potassium chloride has a slight stimulating effect in some soils. In others, however, no action is to be observed.

13. Sodium nitrate decreases the ammonia accumulation in soils supplied with excess energy in the form of dextrose.

14. If arranged in the proper proportions, sodium nitrate, acid phosphate and potassium chloride markedly increase the simplification of organic matter, in a degree beyond which any single application would stimulate.

15. Sodium nitrate loses its stimulating action to a great extent in alkaline soils.

16. This is due to an increase in the numbers of bacteria, which assimilate a considerable proportion of the simplified material, and also to a rearrangement of the soil flora.

17. Of the soil flora studied the soil fungi respond the most to applications of sodium nitrate, with the bacteria next in order.

18. The stimulating influence of sodium nitrate is due to the anion.

19. Sodium nitrate stimulates the nitrification of dried blood, cottonseed meal and to a less extent ammonium sulfate.

20. The stimulative action is not apparent. Secondary reactions, such as increased cell division, with a subsequent assimilation of nitrates, are set up in the system and hide the end point.

21. In large quantities sodium nitrate depresses nitrification, the magnitude of the depression depending first upon the sources of nitrifiable material and second upon the type of soil.

22. In large quantities the presence of sodium nitrate first becomes toxic to the nitrification of ammonium sulfate, then to dried blood and lastly to cottonseed meal.

23. Sodium nitrate in amounts up to 5000 pounds per acre affects *Nitrobacter* the same way as *Nitrococcus*.

24. In amounts beyond 5000 pounds per acre there is evidence to show that *Nitrobacter's* activity is stopped, whereas, that of *Nitrococcus* still manifests itself.

25. Sodium nitrate in small quantities stimulates nitrogen fixation by *Azotobacter*. In larger quantities this salt depresses this process.

26. Large quantities of nitrates are assimilated by biological forms in soils.

27. The amount assimilated is about 20 per cent of the applied nitrogen.

28. The idea is not tenable that calcium nitrate is assimilated to a lesser degree than sodium nitrate.

29. Experiments carried out on the nitrifiability of microbial matter show wide differences in this respect.

30. The entire study of the influence of the sodium nitrate, upon nitrogen transformations in soils seems to indicate rather strongly that in the cases where larger quantities of nitrogen are recovered in the crop than can be accounted for by the amount of sodium nitrate applied, this is due to a drawing

on the soil's own nitrogen supply. This supply is acted upon by a stimulated bacterial flora, brought about by the presence of sodium nitrate.

31. On the other hand, where more or less of the nitrogen applied is recovered the variations in the recovery may in a large measure be explained on the grounds of assimilation of nitrates by soil organisms.

32. Of the three nitrogen-transforming groups of soil organisms sodium nitrate affects the nitrogen-fixing group most adversely, has a lesser detrimental effect on the nitrifying group, and affects the ammonifying group least adversely.

33. As applied in agricultural practice sodium nitrate generally enhances the activity of the ammonifying and nitrifying groups. On the other hand, the activity of the nitrogen-fixing group is discouraged by its presence.

34. In no case will toxicity be caused by sodium nitrate if it is applied rationally.

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